PB-218 484

WATER SUPPLY AND WATER QUALITY CONTROL STUDY, RED RIVER OF THE NORTH BASIN, MINNESOTA AND NORTH DAKOTA

Public Health Service
Kansas City, Missouri

July 1965

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

HE 20.2:
R24/2

5, 2: R24/2

PB 218 484

WATER SUPPLY AND WATER QUALITY CONTROL STUDY RED RIVER OF THE NORTH BASIN

MINNESOTA - NORTH DAKOTA

Study of Needs and Value of Storage for Municipal and Industrial Water Supply and Water Quality Control

MANITOBA
NORTH DAKOTA
MINNESOTA

NATIONAL TECHNICAL
INFORMATION SERVICE

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VI
Kansas City, Missouri

HE 20.2: U.S. HEW
Public Health Service
General publications

R 24/2 Water supply and water quality control study Red River of the North, Minn., study of needs and value of storage for municipal and industrial water supply and water quality control, [July 196
(Region 6, Kansas City, Mo.) [Prepared for Department of Army, Army Engineer District, St. Paul, Minn.]. Environmental Protection Agency.
(
(working & final copies) (no LC number)

WATER SUPPLY AND WATER QUALITY CONTROL STUDY
RED RIVER OF THE NORTH BASIN
MINNESOTA AND NORTH DAKOTA

Prepared for

DEPARTMENT OF THE ARMY

U. S. Army Engineer District

St. Paul, Minnesota

A survey of present water requirements and a projection of 2015 water requirements in the Red River of the North Basin has been made. This investigation discloses a present and future need for municipal and industrial water supply and for storage to regulate streamflow for the purpose of water quality control. Future water requirements are based on projections of population and industrial growth resulting from economic and demographic studies.

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Public Health Service, Region VI
Kansas City, Missouri

July 1965

TABLE OF CONTENTS

Page

LIST OF TABLES. iv

LIST OF FIGURES v

I. INTRODUCTION

Authority I-1

Purpose and Scope. I-2

Acknowledgments. I-2

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings. II-1

Conclusions. II-2

III. PROJECT DESCRIPTION

Location III-1

Streamflow III-1

Water Quality. III-2

Pertinent Data III-2

IV. DESCRIPTION OF STUDY AREA

Location and Boundaries IV-1

Existing Regulation. IV-3

Climate. IV-6

Principal Communities and Industries IV-7

V. WATER RESOURCES

Surface Water. V-1

Ground Water V-12

Page

VI. THE ECONOMY

Introduction VI-1

Present VI-1

Future VI-9

VII. MUNICIPAL AND INDUSTRIAL WATER SUPPLY

Historic Municipal and Industrial Water Use. VII-1

Projected Municipal and Industrial Water Requirements. VII-3

Provision for Municipal and Industrial Supplies. . . . VII-9

Subbasin Municipal and Industrial Water Needs and Existing Sources VII-12

VIII. WATER QUALITY CONTROL

General. VIII-1

Waste Loadings VIII-4

Storage Requirements for Mineral Quality Control . . . VIII-9

Storage Requirements for Dissolved Oxygen Control . . VIII-14

IX. BENEFITS

Municipal and Industrial Water Supply. IX-1

Water Quality Control. IX-5

X. BIBLIOGRAPHY

APPENDIX

LIST OF TABLES

No.	Title	Page
III-1	Principal Tributary Reservoirs Under Construction. .	III-3
IV-1	Existing Federal Reservoirs	IV-3
V-1	Major Tributaries of the Red River of the North in the United States.	V-3
V-2	Climatic Annual Uncontrolled Flow in MGD at Various Locations	V-9
V-3	Surface Water Quality Data.	V-10
VI-1	Potato Production 1954 - 1959	VI-4
VI-2	Sugar Beet Production 1958 - 1963	VI-6
VII-1	Present Major Industrial Water Requirements and Waste Loadings.	VII-2
VII-2	Municipal Water Requirements Per Capita	VII-3
VII-3	Potato Processing Water Requirements and Waste Strength.	VII-6
VII-4	2015 Municipal and Industrial Water Requirements. .	VII-10
VIII-1	2015 Municipal and Industrial Loadings.	VIII-5
VIII-2	Regulation Requirements to Meet Dissolved Oxygen Objectives	VIII-16
IX-1	Value of M&I Water Supply Benefits.	IX-6
IX-2	Value of Water Quality Control Benefits	IX-14

LIST OF FIGURES

No. Page

VIII-1 Schematic Drawing VIII-7

Map of Area. . . . . Following Page . IX-14

APPENDIX

Exhibit No.

Historical Streamflows 1

Municipal Water Supply 2

Municipal Waste Treatment Facilities 3

Historical and Projected Employment for Subarea I through VIII 4

Agricultural Trends. 5

Value of Mineral Production. 6

Manufacturing Trends 7

Population Trend and Projections 8

Information Pertinent to Water Storage Needs 9

Garrison Diversion Unit. 10

I. INTRODUCTION

Authority

The Corps of Engineers, U. S. Army District, St. Paul, Minnesota, in a letter dated February 1, 1963, requested the Public Health Service, Region VI, Kansas City, Missouri, to make a Red River of the North Basin study rather than continue on individual subbasin studies as previously requested. An Inter-Service Supply Support Agreement between the above agencies contained the following specific provisions:

"1. Make a detailed study of the Red River of the North to establish present (1965) and future (2015) needs for water supply and water quality control on the Red River and principal tributaries, and to determine the costs and benefits of all practical measures necessary to meet such needs, except that the Corps of Engineers will estimate the cost of necessary reservoirs for low-flow supplement.

"2. Prepare a report on the study."

This study has been made in accordance with (1) the Memorandum of Agreement dated November 4, 1958, between the

Department of the Army and the Department of Health, Education, and Welfare, relative to Title III, Public Law 85-500 and (2) the Federal Water Pollution Control Act as amended. (33 U.S.C. 466 et seq)

Purpose and Scope

The purpose of this study is to determine the present and future needs and value of municipal and industrial (M&I) water supply and storage for water quality control in the main stem and principal tributaries of the Red River of the North. The study determines water requirements, and the means and benefits (both tangible and intangible) of meeting those requirements for the above purposes.

The scope of this study covers water storage needs during the 50-year study period, 1965 to 2015. Value of benefits is based on 100-year project life.

Acknowledgements

The assistance and cooperation of agencies and individuals who provided data for this report are gratefully acknowledged. Special appreciation is expressed to the following:

U. S. Army Engineers, St. Paul District, Corps of Engineers, St. Paul, Minnesota

Minnesota Department of Health, Division of Environmental Health, Minneapolis, Minnesota

North Dakota State Department of Health, Division of Water Supply and Pollution Control, Bismarck, North Dakota

Bureau of Reclamation, Missouri-Souris Projects Office, Bismarck, North Dakota

U. S. Geological Survey, Water Quality Branch, Topeka, Kansas and Lincoln, Nebraska

U. S. Geological Survey, Ground Water Branch, Grand Forks and Bismarck, North Dakota and St. Paul, Minnesota

Public Health Service, Water Supply and Pollution Control Program, Region VIII, Denver, Colorado

North Dakota Economic Development Commission, Bismarck, North Dakota

North Dakota Water Conservation Commission, Bismarck, North Dakota

Minnesota Department of Business Development, St. Paul, Minnesota

Upper Midwest Research and Development Council, University of Minnesota, Minneapolis, Minnesota

Agricultural and Industrial Development Commission, Great Northern Railroad, St. Paul, Minnesota

North Dakota Agricultural Experimental Station, Fargo, North Dakota

University of Minnesota, Department of Agricultural Economics, St. Paul Campus, Minnesota

University of North Dakota, School of Commerce, Grand Forks, North Dakota

North Dakota State University, Department of Agricultural Economics, Fargo, North Dakota

Red River Valley Potato Growers Association, East Grand Forks, Minnesota

Red Lake River Improvement Association, Crookston, Minnesota

American Crystal Sugar Company, E. Grand Forks, Minnesota and Denver, Colorado

Land O'Lakes Company, Thief River Falls, Minnesota

Research Department, Federal Reserve Bank of Minneapolis, Minneapolis, Minnesota

Manitoba Department of Agriculture and Conservation, Winnipeg, Manitoba, Canada

Manitoba Department of Health, Winnipeg, Manitoba, Canada

Manitoba Department of Industry and Commerce, Winnipeg, Manitoba, Canada

Water and Sewage Commission and Water Works Department, Fargo, North Dakota

Chamber of Commerce and Urban Renewal Agency, Fargo, North Dakota

Water Department, Grafton, North Dakota

Municipal Utilities, Valley City, North Dakota

Mayor's Office and Water Department, Walhalla, North Dakota

Water Department, Grand Forks, North Dakota

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings

1.) This study of the present (1965) and future (2015) need for and value of storage for water supply and water quality control on the Red River of the North and its principal tributaries is especially concerned with eight reservoirs on the tributaries which are under consideration by the Corps of Engineers. The name and location of these reservoirs are on the Study Area map following Page IX-15.

2.) There are 11 principal communities which had a 1960 population of 4,000 or greater and one standard metropolitan statistical area in the basin. The food and kindred products industry, consisting mainly of sugar beet, potato, and turkey processing, has large industrial water requirements and waste returns in the basin.

3.) The study area includes 36 counties in eastern North Dakota and northwestern Minnesota which cover the Red River of the North basin from the headwaters to the international boundary. To facilitate the investigation, the study area is divided into eight subareas on the basis of counties with similar geography and/or economies.

4.) In 1960, the total population of the study area was 573,321. Thirty-four percent of this total or 192,572 persons were in urban, while sixty-six percent or 380,749 persons were in rural.

Conclusions

1.) The total population of the Red River of the North study area is expected to reach 760,000 by 2015. Of this total, 550,000 is expected to be urban, while the remaining 210,000 is rural.

2.) Based on projected conditions of economic activity and population growth, the significant 2015 water requirements for municipal and industrial use total 110 mgd. The recommended storage to meet the 2015 municipal and industrial water requirements is that necessary to deliver the following quantities to the respective trading centers:

Trading Center	mgd
Neche	.02
Pembina	.02
Cavalier	.05
Grafton	.40
Hallock	.04
Stephen	.04

The other trading centers are expected to meet their 2015 municipal water requirements from presently available sources.

The foregoing recommended storages are based only on analysis of availability of quantities of water. The ground water supplies for many communities are of inferior quality, i.e., do not meet PHS drinking water standards. Such communities should be given the opportunity to avail themselves of the superior quality water from project reservoirs.

3.) The values of storage for municipal and industrial water supply purposes are listed below. The dollar values given at the reservoir are for the recommended storage volume and have been amortized over 100 years and discounted from the year of first need at 3-1/8 percent rate of interest.

Value of Storage at	To	First Need	1965 Annual Value ($1000)	1965 Annual Value ($/1000 Gal.)
Pembilier	Pembina	1980	None	None
	Neche	1980	12.59	1.66
	Cavalier	1980	.4	0.02
Reservoir Upstream Grafton	Grafton	1990	5.9	0.04
Reservoir Upstream Hallock	Hallock	1965	2.1	0.14
Reservoir Upstream Stephen	Stephen	1965	.7	0.05

4.) Based on existing conditions, expected municipal and industrial wastes, and the evaluatable portion of Federally authorized water resources development[1/] affecting the quality of the Red River of the North, streamflow regulation requirements and their resultant benefits as follows:

Location of Storage	Annual Storage Requirement (Ac. Ft/Yr)	Year of First Need	1965 Annual Value ($1,000)
Ab. Homme Res.	1,460	1965	10
Upstream Barnesville	770	1980	6
Upstream Detroit Lakes	670	1985	9
E. Tribs ab. Fargo	80,000	2/	165
Kindred Dam	60,000[3/]	4/	145

1 / Does not include restoration of Devil's Lake.

2 / Operation of Oaks irrigation unit draining to the Wild Rice River of North Dakota.

3 / Based on provision for salt holding behind Kindred during low flow periods; comparable control of quality at Grand Forks can be obtained by providing 150,000 acre-feet of dilution storage in eastern tributary reservoirs upstream from Grand Forks.

4 / Operation of Warwick - McVille and New Rockford units draining to the Sheyenne River.

The value of benefits for the provision of storage for water quality control is based on the most likely alternatives.

5.) Maintenance of a satisfactory water quality in the Red River of the North Basin will benefit a wide spectrum of water uses in the study area, which include: reduction in the public health hazard in downstream municipal water supplies; improvement of tastes and general physiological acceptance of public supplies; lower water treatment costs; reduction in the health danger to livestock; reduction in damage to the aquatic life; improved recreational opportunities in boating, fishing, swimming and water skiing; continuing aesthetic enjoyment of the streams and lakes, and prevention of serious degradation of quality at the International boundary. From the above, it is concluded that the benefits are widespread in scope, and warrant the provision of non-reimbursable storage for the required streamflow regulation. The total benefits from storage for regulation of streamflow for quality control purposes will be obtained only if adequate treatment is provided.

6.) Preliminary computations with gross data indicate that restoration of Devil's Lake can be accomplished with maximum speed and minimum water quality degradation only through a closely controlled system of releases to the Sheyenne, holding and mixing in Lake Astabula and Kindred reservoir, and maximum use of the diluting capabilities of unregulated flow to the Red River and of all releases from tributary reservoirs. To achieve this necessary control will require detailed mathematical models for predicting stream quality response, a network for environmental monitoring and short-term prediction, and close coordination among all interested parties.

III. PROJECT DESCRIPTION

Location

The main stem and principal tributaries in the Red River of the North Basin are being studied by the St. Paul District Office, Corps of Engineers, to determine whether multiple-purpose reservoir development may be desirable and economically justified. Eight reservoirs are presently under consideration on seven principal tributaries located in Minnesota and North Dakota. The location of these reservoirs can be seen on the Study Area map.

Streamflow

Historical streamflow data on the principal tributaries on which reservoirs are under consideration, giving maximum, minimum, and average discharges of record, are shown in Exhibit No. 1. The uncontrolled streamflows at the mouth of these tributaries are given at four recurrence intervals in Table No. V-3. Spring streamflows which result from snowmelt are of major significance in seasonal streamflow distribution. Streamflow during most of the year is usually many times lesser than flow during the Spring breakup.

Water Quality

Data pertaining to water quality in the main stem and principal tributaries of the Red River of the North are summarized in Table No. V-4. Average, maximum, and minimum concentrations of total dissolved solids (TDS), sulfates (SO_4), chlorides (Cl), silica (Si), hardness and bicarbonate hardness (HCO_3) are presented in the table. In general, the concentrations of TDS, SO_4 , and Cl in the water of the main stem and east bank tributaries of the Red River of the North are less than the maximum limits set forth in the 1962 Public Health Service Drinking Water Standards.[63] The concentrations of one or more of these constituents in the water of the Bois de Sioux and west bank tributaries exceed the maximum limits most of the time.

Pertinent Data

Pertinent data on the eight tributary reservoirs under consideration are in Table No. III-1. This table presents the contributing drainage areas and river mile locations of the reservoirs, streamflow travel times, and storage.

Table No. III-1

Principal Tributary Reservoirs Under Consideration

Red River of the North Basin Study

Tributary Storage Location	Contributing Drainage Area (Sq. Miles)	Storage Site To Mouth		Mouth To Int. Bdry.		Total Travel Time	Storage at Maximum Elevation (Acre-Feet)
		River Mile	Travel Time	River Mile	Travel Time		
Pembina River, N. Dakota Pembilier Reservoir*	2,715	94	4	3	0	4	525,000
Park River, N. Dakota Reservoir above Homme Res.	229	65	3**	67	3	6	19,500
Goose River, N. Dakota Res. near Beaver Creek	415	80	3	202	9	12	58,000
Sheyenne River, N. Dakota Kindred Reservoir	2,970	75	3 1/2	273	11	14 1/2	410,000
Buffalo River, Minnesota Hawley Reservoir	300	52	2	262	11	13	--
Wild Rice River, Minnesota Twin Valley Reservoir	880	74	3	225	10	13	82,000
Red Lake River, Minnesota Reservoir near Huot	3,615	70	3	143	7	10	162,000
Reservoir near Red Lake Falls	1,525	92	4**	143	7	11	--

*The Pembilier dam has been proposed with a spillway crest elevation of 1,116.0 feet, with total storage of 290,000 acre-feet at spillway level and with 130,000 acre-feet of storage for water supply and irrigation. 21/

** With no detention in downstream reservoir.

NOTE: Travel time is in days under low-flow conditions

IV. DESCRIPTION OF STUDY AREA

Location and Boundaries

The Red River of the North Basin includes the northeastern corner of South Dakota, eastern North Dakota, northwestern Minnesota, and a portion of Manitoba, Canada. The basin is located almost at the geographic center of the North American Continent.

The study area includes that portion of the basin which lies in Minnesota and North Dakota. To facilitate the development of existing data, the study area is confined within county lines. Parts of two counties in South Dakota are in the basin. These counties have little land area and a limited population in the basin and are excluded from the study area. The study area consists of 36 counties which are entirely or partially in the drainage basin. The study area map shows the boundaries and location of the study area.

The study area is divided into subareas to strengthen the investigation of water supply and water quality control needs. Counties with similar geography and economies are grouped together by Standard Metropolitan Statistical Areas (SMSA), trading centers, and hydrologic boundaries.

The smallest number of subareas found practical is eight.

The counties were grouped as follows:

Subareas	Counties	Major Tributaries
I	Kittson, Minnesota	Pembina River
	Roseau, Minnesota	Snake River
	Marshall, Minnesota	Park River
	Cavalier, N. Dakota	Two Rivers
	Pembina, N. Dakota	Roseau River
	Walsh, N. Dakota	Forest River
II	Beltrami, Minn. (part)	Red Lake River
	Clearwater, Minn.	Turtle River
	Polk, Minnesota	Sand Hill River
	Red Lake, Minnesota	
	Pennington, Minnesota	
	Grand Forks, N. Dakota	
III	Traill, N. Dakota	Goose River
	Steele, N. Dakota	
IV	Norman, Minnesota	Wild Rice River (Minnesota)
	Mahnomen, Minnesota	Marsh River
V	Cass, N. Dakota	Sheyenne River, lower
	Clay, Minnesota	Buffalo River
VI	Barnes, N. Dakota	Sheyenne River, upper
	Griggs, N. Dakota	
	Eddy, N. Dakota	
	Wells, N. Dakota	
	Ransom, N. Dakota	
	Sargent, N. Dakota	
VII	Becker, Minnesota	Wild Rice River (N. Dakota)
	Otter Tail, Minn.	Otter Tail River
	Wilkin, Minnesota	
	Grant, Minnesota	
	Traverse, Minnesota	
	Richland, N. Dakota	
VIII	Towner, N. Dakota	Devil's Lake Basin
	Rolette, N. Dakota	
	Pierce, N. Dakota	

Subareas	Counties	Major Tributaries
VIII Cont'd.	Benson, N. Dakota Ramsey, N. Dakota Nelson, N. Dakota	

Existing Regulation

The Corps of Engineers presently operates five reservoir projects within the Red River of the North Basin. Locations of the reservoirs are shown on the Study Area map, and pertinent data are given in Table No. IV-1.

Table No. IV-1

Existing Federal Reservoirs

Red River of the North Basin Study

		Storage Allocation in Acre-Feet		
Existing Reservoir	Flood Control	Water Supply	Conservation Pool	Total Usable for Flood Control and Water Supply
Lake Traverse	137,000	-	112,500	137,000
Orwell	13,100(1)	13,100(1)	1,000	13,100
Lake Ashtabula	69,500(1)	69,500(1)	1,200	69,500
Red Lakes	870,000	960,000(2)	850,000	1,830,000
Homme	3,380(1)	3,380(1)	270	3,380

(1) Dual-use storage.
(2) Major portion not always available due to evaporation from surface area of 440 square miles.

Four of these reservoirs have storage allocated to water supply and pollution abatement. The three dual-use storage projects are operated to impound water during spring flood periods with subsequent releases of the stored water for water supply and pollution abatement during the low flow periods. Dual-use storage is compatible with the streamflow pattern in the study area, and under present operation the use of the storage for flood control does not infringe upon the reservoirs' water supply allocations.

The project plans for Orwell, Lake Ashtabula, Red Lakes and Homme are in House Document No. 185, 81st Congress; Senate Document No. 193, 78th Congress; House Document No. 345, 78th Congress; and Senate Document 194, 78th Congress respectively.

Other Federal projects include a number of shallow impoundment areas in the basin varying from less than 50 acres to 28,120 acres (Mud Lake refuge northeast of Thief River Falls, Minnesota) which have been constructed and are maintained by the U. S. Fish and Wildlife Service primarily for wildlife propagation. In the North Dakota portion of the basin about 80 small detention dams, to retard erosion and runoff, have been constructed under the supervision of the U. S. Soil Conservation Service. More recently under the Watershed Protection and Flood Prevention Act (P.L. 566), a number of projects are being planned and constructed in the basin. These work plans study nearby municipal and industrial water supply needs and include storage for that purpose when assurance of purchase is obtained. None of these structures have a significant impact on future storage needs evaluated in this report.

Existing non-Federal projects include a large number of water conservation projects consisting of lake outlet control structures in Minnesota and detention dams on tributaries in North Dakota. Financed in part by Federal relief funds in the 1930's, 95 structures were constructed in the North Dakota portion of the basin and about 50 in the Minnesota. A number of dams have been constructed by municipalities and private interests on the main stem and tributaries of the Red River of the North. There are five low-head dams on the main stem at Fargo, one at Grand Forks and one at Drayton. These dams are used primarily to augment local water supply. 18/ There are nine small water power developments in the basin located on the Otter Tail and Red Lake Rivers in Minnesota. 10/

Climate

Throughout the valley the mean annual rainfall from available records of all stations is 20.11 inches; average annual precipitation varies from about 24 inches in the southeast portion to 17 inches in the northwest portion of the basin. The mean annual temperature varies from 43°F. in the south to 36°F. in the north but daily extremes of 118°F. and -54°F. have been recorded. Winter months are normally the driest, while the greatest amount of precipitation occurs during the period of May through August. Precipitation in winter generally occurs as snow and constitutes about 15 percent of the total annual amount. Average annual evaporation from water surfaces is approximately 36 inches. Annual runoff varies from 0.54 inches to 3.55 inches; the average for the basin is 1.25 inches. Runoff varies greatly with high flows occurring generally throughout the basin in the spring during the snow-melt period. The spring breakup period is followed by gradually declining streamflows subject only to minor fluctuations from rainfall until late summer or fall when near zero flows are experienced. Several streams in the basin have little or no flow through the winter season.

Principal Communities and Industries

The principal communities in the study area are: Breckenridge, Crookston, Detroit Lakes, East Grand Forks, Fergus Falls, Moorhead, and Thief River Falls in Minnesota and Devil's Lake, Fargo, Grafton, Grand Forks, Valley City and Wahpeton in North Dakota. The 1960 population of the smallest of these communities was 4,335. Exhibit No. 2 lists all communities which have constructed a municipal water supply system.

The food and kindred products industry has major water requirements and waste water disposal in the study area. Beet sugar, potato products, dairy products, and meat products are of principal significance in this industry.

V. WATER RESOURCES

Surface Water

The Red River of the North has its source in Lake Traverse. Lake Traverse is drained by the Bois de Sioux River which joins the Otter Tail River at Breckenridge, Minnesota, to form the Red River of the North. Of the 1,875 square miles of drainage area above the confluence of these two rivers, 1,320 square miles are tributary to Lake Traverse.

From the confluence of the Otter Tail and Bois de Sioux Rivers the Red River of the North flows 400 miles in a northerly course, forming the boundary between Minnesota and North Dakota, to the International Boundary between the United States and Canada. From the International Boundary it flows in a northwesterly direction for 155 miles into Canada to Lake Winnipeg. The drainage area of the Red River of the North, at the International Boundary, is 40,200 square miles, of which approximately 5,800 square miles are noncontributing. Of this noncontributing drainage area 3,944 square miles consist of the Devil's Lake subbasin with the balance in the upper reaches of the Sheyenne River drainage area. Included in the basin is an area of about 2,000 square miles in Canada which drains southeastward into the United States through the Pembina River and an area of about 1,200 square miles in the Roseau River Basin in Minnesota, although the Roseau River joins the Red River a few miles north of the International Boundary. There are approximately 21,000 square miles of drainage area in North Dakota and 16,400 square miles in Minnesota. Table No. V-1 shows the major tributaries of the Red River of the North.

Table No. V-1

Major Tributaries of the Red River of the North in the United States

Red River of the North Basin Study

Stream	Approximate Length (Miles)	Drainage Area (Square Mile)
Headwater		
Bois de Sioux River, N. & S. Dakota	34	1,875
West Side Tributaries - North Dakota		
Wild Rice River	243	2,300
Sheyenne River	500	3,623 a,b/
Maple River	-	1,837 c/
Goose River	186	1,280
Turtle River	-	700
Forest River	147	1,000
Park River	110	1,130
Pembina River	275	3,790
East Side Tributaries in Minnesota		
Otter Tail River	200	2,000
Buffalo River	88	1,100
Wild Rice River	190	1,640
Red Lake River	200	5,562
Snake River	60	1,040
Tamarac River	47	580
Two Rivers	76	776
Roseau River	180	2,060

a/ Excluding approximately 5,800 square miles which are noncontributing

b/ Above mouth of planned canal between Sheyenne River and Red River of the North

c/ From canal to mouth of Sheyenne River including Maple River

Historical hydrologic data in the Red River of the North basin including drainage area, length of record, estimated river miles, maximum, minimum, and average discharge are shown in Exhibit No. 1 of the Appendix.

The construction of the Garrison Diversion Unit would result in an interbasin transfer of water. Full development of this million acre irrigation project would result in about 600,000 acre-feet of return flow entering the Red River of the North Basin. Exhibit No. 10 describes this project.

Quantity of Water

The total surface water flows are described in terms of dependable uncontrolled flow and dependable controlled flow from reservoirs or other sources. This includes natural runoff for which probability of occurrence can be established and predictable releases from allocated conservation storage. Release from flood control storage is unpredictable, i.e., undependable and exlcuded from the Hydrologic Base System.

To determine the dependable uncontrolled flow, flow frequency curves are developed. Each curve is a plot of the climatic annual mean discharge in mgd per square mile versus recurrence interval in years. The records on which the curves are based are selected on the basis of the geographic location of the gaging station and the length of record.

The climatic annual uncontrolled flows at different locations and recurrence intervals are shown in Table No. V-2. These are the predictable natural flows downstream from the existing Federal reservoirs. Distributions of median monthly flows are significantly different in the basin. Monthly flow distributions determined at each location where a flow frequency curve was developed are applied in conjunction with the appropriate curve. Indicative of the type of distribution in the basin is the median monthly streamflows in the Red River at Grand Forks which is the combined flow from most of the major tributaries. The minimum monthly flow in January or February is 0.01 of the maximum flow in April. The flow in April and May is more than 40 percent of the annual flow.

There are four existing Federal reservoirs with storage allocated to water supply. The amount of water supply storage is given in Table No. IV-1. Homme, Orwell and Lake Ashtabula contain dual-use storage allocated for water supply and flood control. The use of the same storage space for more than one purpose is dual-use storage. In this basin dual-use storage does not infringe on allocations for water supply. These three reservoirs, plus the Red Lakes, have storage allocated to water supply.

After the spring breakup, Homme Reservoir is held to as near normal pool elevation as possible. Releases are made to satisfy water supply and pollution control needs downstream. Winter drawdown to provide flood storage for the spring run-off begins about November 1.

This winter release of storage serves to augment the flow downstream during the ice cover period. By March 1, the reservoir pool should be drawn down enough to provide storage for the expected spring runoff. [30]

Lake Ashtabula is held as near as possible to normal pool elevation after the spring breakup. Releases are made to satisfy water supply and pollution control needs downstream. Winter drawdown begins about October 1, and should be completed by March 1 to provide storage for the expected spring runoff. At least 3 cubic feet per second must be released at all times for water supply use downstream. [29]

Following spring breakup, Orwell Reservoir is drawn down in anticipation of summer floods. The pool elevation varies through the summer months in order to assure that the reservoir will be filled to normal full pool by September 20. The winter drawdown should be completed by March 1 for spring runoff. At least 5 cubic feet per second must be maintained at all times for water supply use downstream. [28]

The release of water from the Red Lakes is controlled by treaty with the Indians and based upon lake elevations. The storage allocated to water supply and pollution abatement in these four reservoirs is uncommitted, i.e., not purchased under the enabling provisions in the Water

Supply Act of 1958. However, in the operation of these reservoirs water supply and pollution abatement are given primary consideration. Inasmuch as justification for construction was mainly based on water supply and pollution abatement benefits, it is unlikely that these allocations will be changed and, therefore, the releases are considered dependable.

The dependable releases can be added to the uncontrolled flows shown on Table No. V-2 in the Hydrologic Base System.

The depletion of the total surface water flow varies by seasons due to the practice of controlling M&I return flows. This practice is expected to become more prevalent in the future, resulting in increased streamflow during the discharge seasons and in decreased streamflow during the other seasons. For additonal detail, see Exhibit No. 9.

Quality of Water

A composite of the available data on the concentration of TDS, SO4, Cl, Si, Hardness and HCO_3, of surface water is presented in Table No. V-3. Table No. V-3 gives the maximum, minimum, and mean concentration in a specified number of samples. Where there is a duplication on the table, the data came from different sources and the method of sampling and points of collection are not the same. In Table No. V-3, mean concentrations exceed the maximum limits for sulfates, chlorides, and total dissolved solids established by the 1962 Public Health Service Drinking Water Standards at several locations. In general the data show that the waters in the Bois de Sioux River and west bank tributaries of the Red River of the North have mineral concentrations which frequently exceed the maximum limits while the east bank tributaries are of a satisfactory quality.

Table No. V- 2

Climatic Annual
Uncontrolled Flow in MGD at Various Locations

Red River of the North Basin Study

Recurrence Interval (Years)	2.00	3.33	10.0	50.0
Location Probability	.50	.30	10	.02
At the mouth of the Otter Tail River	11	5	2	1
At Fargo in Red R. above canal except Otter Tail R.	101	57	16	12
At Fargo above mouth of canal	112	62	18	13
At Fargo in mouth of canal	43	20	15	14
At confluence of canal and Red River	155	82	33	27
Inflow between mouth of canal and mouth of Buffalo River	3	2	1	0
At the mouth of the Sheyenne River	17	14	6	5
At the confluence of the Sheyenne R & Red R	175	98	40	32
At the mouth of the Buffalo River	165	128	75	64
At the confluence of the Buffalo R and Red R	340	226	115	96
Inflow between mouth of the Buffalo R & Wild Rice	8	4	2	1
At the mouth of the Wild Rice River	139	85	48	33
At the confluence of Wild Rice R & Red R	487	315	165	130
Inflow between mouth of Wild Rice River and mouth of Goose River	3	2	1	1
At the mouth of the Goose River	16	8	4	2
At the confluence of the Goose R & Red R	506	325	170	133
Inflow between mouth of Goose R & Red Lake R	21	11	6	3
At the mouth of the Red Lake River	361	202	69	43
At the confluence of Red Lake R & Red R	888	538	245	179
At the mouth of Turtle River	12	9	4	3
At the mouth of Forest River	17	13	6	4
At the mouth of Snake River	62	35	10	10
At the mouth of Park River	15	12	6	4
At the mouth of Tamarac River	35	20	6	6
Inflow between Red Lake and Drayton	12	7	4	2
Flow at Drayton	1041	634	281	208
At the mouth of Two Rivers	47	26	8	8
At the mouth of Pembina River	87	54	22	5
Drayton & Emerson not included above	30	18	12	5
Flow at international boundary	1205	732	323	226

Table No. V-9

Surface Water Quality Data
(Milligrams per Liter)

Red River of the North Basin Study

Location	Total Dissolved Solids No. of Anal. Mean	 Max. Min.	Sulfate (SO$_4$) No. of Anal. Mean	 Max. Min.	Chloride (Cl) No. of Anal. Mean	 Max. Min.	Silica (Si) No. of Anal. Mean	 Max. Min.	Hardness (as CaCO$_3$) No. of Anal. Mean	 Max. Min.	Bicarbonate Hardness No. of Anal. Mean	 Max. Min.
Roseau River at boundary	1 261	– –	1 49	– –	1 1.0	– –	– –	– –	1 206	– –	1 225	– –
Pembina River at Neche	1 402	– –	1 136	– –	1 9.1	– –	1 18	– –	1 236	– –	1 204	– –
Pembina River at Walhalla	39 504	822 211	39 167	255 41	39 13.0	20 0.0	34 24	31 11	39 285	543 116	39 247	485 98
South Branch Two Rivers	1 360	– –	1 72	– –	1 1.0	– –	– –	– –	1 304	– –	1 306	– –
Two Rivers at Hallock 24/	– –	– –	2 90	100 80	2 4.6	7.0 2.2	– –	– –	– –	– –	– –	– –
Two Rivers below Hallock 27/	1 413	– –	1 67	– –	1 59	– –	– –	– –	1 288	– –	1 238	– –
North Branch Two Rivers at Lancaster	2 477	640 314	2 52	64 41	2 52	64 41	– –	– –	2 282	364 200	2 279	354 204
Red River at Drayton	3 371	388 347	3 71	100 39	3 34	51 20	1 20	– –	3 241	252 222	3 246	272 211
Tamarac River at Stephen	– –	– –	3 76	125 50	3 5.3	9.0 3.5	– –	– –	– –	– –	– –	– –
Homme Reservoir	6 492	666 221	6 182	247 62	6 12.8	16 2.5	6 20	23 17	6 298	434 115	6 216	310 104
Park River near Grafton	1 790	– –	1 256	– –	1 138	– –	1 5.4	– –	1 312	– –	1 228	– –
Park River at Oakwood	1 1,440	– –	1 128	– –	1 396	– –	1 6.2	– –	1 346	– –	1 638	– –
Middle River near Strandquist	1 315	– –	1 30	– –	1 2.0	– –	– –	– –	1 271	– –	1 316	– –
Tamarac River near Strandquist	1 392	– –	1 12	– –	1 7.5	– –	– –	– –	1 309	– –	1 438	– –
Red River at Oslo 27/	3 294	341 220	4 75	99 43	4 17	23 8	3 12	11 13	4 212	263 164	4 186	235 156
Red River at Oslo 24/	– –	– –	1 55	– –	1 20	– –	– –	– –	– –	– –	– –	– –
Red River at Grand Forks 27/	115 369	540 199	116 76	152 34	63 9.9	29 0.5	62 12.7	35 1.8	139 267	468 140	137 269	480 135
Red River at Grand Forks 22/	49 415	519 310	44 56	152 0	50 16	38 8	– –	– –	51 279	356 208	 –	– –
Lower Red Lake near Red Lake	1 180	– –	1 12	– –	1 0	– –	1 5	– –	1 146	– –	1 171	– –
Red Lake River at Thief River Falls	– –	– –	1 70	– –	1 3.0	– –	– –	– –	– –	– –	– –	– –
Red Lake River at Crookston 23/	1 182	– –	1 33	– –	1 1.0	– –	1 9.4	– –	1 123	– –	1 116	– –
Red Lake River at Crookston 24/	– –	– –	2 90	150 29	2 5.0	8.0 2.0	– –	– –	– –	– –	– –	– –
Red Lake River at East Grand Forks 24/	– –	– –	1 62	– –	1 15	– –	– –	– –	– –	– –	– –	– –
Red Lake River at East Grand Forks 27/	14 313	436 238	– –	– –	10 6.8	13 1.5	– –	– –	– –	– –	– –	– –
Goose River near Portland	1 443	– –	1 178	– –	1 7	– –	1 16	– –	1 295	– –	1 184	– –
Goose River at Hillsboro	1 625	– –	1 236	– –	1 49	– –	1 14	– –	1 334	– –	1 218	– –
Red River at Halstad	3 299	347 210	3 57	69 37	3 11	14 5	3 11	13 8	3 207	261 164	3 215	279 143
Buffalo River near Dilworth	1 246	– –	1 70	– –	1 0	– –	1 13	– –	1 172	– –	1 161	– –
Sheyenne River near Warwick	276 489	1,230 150	145 100	228 28	99 13	140 0.6	55 20	35 2.9	262 243	572 71	– –	– –

Table No. V-3

Surface Water Quality Data
(Milligrams per Liter)

Red River of the North Basin Study

Location	Total Dissolved Solids		Sulfate (SO_4)		Chloride (Cl)		Silica (Si)		Hardness as $CaCO_3$		Bicarbonate Hardness	
	No. of Anal. / Mean	Max. / Min.	No. of Anal. / Mean	Max. / Min.	No. of Anal. / Mean	Max. / Min.	No. of Anal. / Mean	Max. / Min.	No. of Anal. / Mean	Max. / Min.	No. of Anal. / Mean	Max. / Min.
Sheyenne River near	20	719	[illegible]	184	17	26	17	33	20	401	20	521
Cooperstown	525	143	128	29	15.9	0.1	22	11	283	76	333	80
Lake Ashtabula	6	595	6	158	6	23	6	22	6	292	6	369
	489	396	125	92	16	9	17	15	241	197	309	257
Sheyenne River below	18	593	19	158	19	26	18	22	19	296	19	367
Baldhill Dam	403	300	100	69	13.2	9.7	7.9	0.5	207	168	271	187
Sheyenne River at Lisbon	86	832	86	282	19	78	19	26	100	409	100	459
	517	185	147	39	35.3	8.4	12.4	3.9	261.7	102	276.9	106
Red River at Fargo 26/	144	650	144	267	92	12.0	92	18	159	420	159	379
	321	174	67	13	5.5	0.0	10.9	3.0	266	118	269	103
Red River at Waterworks	15	405	–	–	16	16	–	–	–	–	–	–
Intake, Fargo 27/	332	273	–	–	4.7	1.5	–	–	–	–	–	–
Wild Rice River near Cayuga	11	2,970	11	1,290	11	414	11	22	11	660	11	426
	716	78	293	13	58.6	18	12.3	5.5	244	36	193	32
Wild Rice River near	1	–	1	–	1	–	1	–	1	–	1	–
Abercrombie	129	–	24	–	2.8	–	8.4	–	58	–	51	–
Otter Tail River below	4	275	4	32	4	4	4	16	4	237	4	278
Orwell Dam	259	246	25	27	3	2	12	10	222	204	253	225
Otter Tail River at	14	332	–	–	14	25	–	–	–	–	–	–
Breckenridge	290	265	–	–	5.0	1.0	–	–	–	–	–	–
Rabbit River near Campbell	2	1,350	2	717	2	12	2	12	2	730	2	250
	934	519	482	247	8.7	5.5	10	9.0	521	313	207	163
Mud Lake near Wheaton	4	747	4	424	4	13	4	5.6	4	430	4	130
	739	736	403	381	12	11	3.2	2.3	427	424	126	122
Lake Traverse near Wheaton	9	2,300	9	1,280	9	42	9	21	9	1,280	9	379
	1,220	738	660	405	19	11	19.9	3.9	691	437	221	162
Mustinka River above Wheaton	3	1,360	3	822	3	7.1	3	10.0	3	808	3	265
	998	586	551	300	5.3	3.4	5.9	3.5	617	376	200	160

Source: Geological Survey 25,26/, Minnesota Department of Health 23,24,27/ and Public Health Service 22/

Ground Water

The importance of ground water in the Red River of the North Basin can be measured by its use. The source of supply for 84 percent of the municipal water systems in the basin is ground water. Refer to Exhibit No. 2. Though an inventory of industrial source of supply is not available, 100 industrial plants are known to use ground water as a source of supply. [6] Practically the entire rural population obtains its needed supply of water through wells or from springs. [87] Ground water is not used in any significant amount for irrigation.

Most of the known and developed aquifers in the basin are small with limited yields. The water is often undesirable because of poor quality, especially in the western portion of the basin.

Minnesota

Most of the Red River of the North Basin in Minnesota is covered by the bed of glacial Lake **Agassiz**. The area is very flat; even the ancient beach ridges are so low that they are barely noticeable. The Lake Agassiz plain covers about 5,000 square miles of northwestern Minnesota. The plain is underlain by lake deposits and then glacial drift over sediments of Cretaceous age. These sediments overlay Precambrian rocks that contain little water of any kind or Paleozoic rocks that contain saline water. Paleozoic rocks are present only in the northwestern corner of the state.

The Cretaceous sediment consists mostly of soft shale, but includes thin beds of sand which are not highly productive but are important aquifers in this area of meager supply. In some areas the water from these aquifers is also saline.

The glacial drift is the most important aquifer. These deposits yield moderate supplies of water that are generally hard and usually high in iron and in some areas high in hydrogen sulfide content.

Large diameter shallow wells are required to obtain water from the lake deposits. Such wells are vulnerable to pollution and drought.

Most public and industrial water supplies are obtained from buried glacial outwash. In this area there is no ground water used for irrigation.

North Dakota

In the Red River of the North Basin the main water-bearing formations are (a) alluvium of Quaternary age and (b) consolidated sedimentary rocks of Cretaceous age.

Alluvium (a) along present streams is only of importance on the Sheyenne River, a tributary of the Red River. Along the Red River and its tributaries ground water supply is small.

Glacial outwash is also included in the term "alluvium" as used here. The glacial outwash may be found in channels of pre-glacial drainage under glacial drift, in abandoned channels of glacial drainage.

which may be at any location in the drift, or in irregular sheets within the drift. In the North Dakota portion of the Red River Basin, known areas in which moderate to large ground-water supplies may be available from the sand and gravel of the outwash are: (1) A large area at the junction of Eddy, Ramsey, Nelson, and Benson Counties, (2) an area in Grand Forks County at and north of Larimore, (3) a small area near Lisbon in Ransom County, (4) a small area in the vicinity of Leyden in northwestern Pembina County, (5) an area along the eastern boundary of Ransom County, (6) the Fargo-Moorhead area in Cass County, North Dakota, and Clay County, Minnesota, (7) the Maple River valley flowing-well area in western Cass County, and (8) several areas adjacent to the Sheyenne River.

The water in the alluvium is highly variable in composition, but in general it is quite mineralized, most of it containing more than 1,000 mg/l of dissolved solids.

Where quantities are not available from the alluvium for even domestic or stock uses, water is generally available from bedrock below the alluvium.

The primary water-bearing bedrock (b) the Red River of the North Basin includes the Lakota Formation and its Fuson Member, of Early Cretaceous age, and the Dakota Sandstone of Late Cretaceous age. These or similar formations underlie all of the Red River of the North Basin in North Dakota except a strip 5 to 25 miles wide along the eastern edge. All of the basin in North Dakota except this strip can be considered the North Dakota part of the famous Dakota Artesian Basin. In the early days thousands of flowing wells were drilled to the artesian sandstone by a jetting process which enabled drilling 1¼-1½ inch wells to depths of over 1,000 feet at a small cost. This was done to obtain supplies of water where the lake deposit or glacial drift yield was inadequate. The artesian head has declined greatly and most wells have ceased to flow or flow only a few gallons per minute.

The high initial yield of wells was due to high head rather than high permeability as the sandstone is not very permeable. The yield has steadily decreased with the decline in head resulting from the drilling and unrestrained flow of the thousands of wells. This large area is approaching a rate close to what must be the perennial yield. The bedrock aquifers yield a water of variable quality; in general the water is moderately mineralized and in some places it is saline. The sodium level in much of it is high and would not be suitable for irrigation, but pumpage yields are generally not high enough for irrigation anyway.

The strip at the eastern edge of the state where Cretaceous aquifers are absent is perhaps five miles wide at the South Dakota line, widens to about 20 miles in Cass County, narrows to 10 to 15 miles in Grand Forks County, and is about 25 miles wide in Pembina County. In this strip there is no aquifer since the Cretaceous is missing or is represented by a non-water-bearing clay lying on crystalline bedrock.

VI. THE ECONOMY

Introduction

An assessment of future municipal and industrial and quality control water needs in the Red River of the North Basin involves an appraisal of the area's future industrial and population growth potential. The increasing regional and national demand for goods and services affords an opportunity for attracting new industries and expanding existing ones. However, prospects for growth in the Red River of the North study area depend on their competitive advantages over other areas.

A study of the population and employment changes along with an analysis of the resource situation has been necessary in serving as a basis for projecting the future municipal and industrial water requirements and waste discharges.

The study area was divided into eight arbitrary subareas. Generally, each subarea contains two or more counties which include one or more major trading centers. The Fargo-Moorhead Standard Metropolitan Statistical area was considered as one complete subarea. Each subarea boundary follows county lines to facilitate the use of economic data which is primarily shown by county division. Section IV details subarea groupings.

Present

General

In 1960, almost one-third or about 62 thousand persons of the total labor force (197,364) were employed on the farm. Five percent of the total labor force or slightly over 10 thousand persons were employed in manufacturing, while less[31/] than one percent or less than 200 persons were employed in mining.

The largest portion of the labor force (112,835 persons or 57 percent) were employed in the dependent industries listed under the service category (including construction, transportation, communications, utilities, retail and wholesale trade, public administration, and personal services). The remaining six percent was unemployed. See Exhibit No. 4 for employment data. [31/]

Agriculture

Agriculture and its related activities have been the most important segments of the Red River of the North Basin's basic economy. This has been true historically and is expected to continue in the future.

Agricultural employment in the study area has decreased from about 103 thousand in 1940 to about 62 thousand in 1960. During the period from 1949 to 1959, the number of farms decreased from about 62 thousand to about 50 thousand. Despite the decline in the number of farms and farmers over the last 20 years, agricultural production when measured by dollar returns is expanding in the study area. The dollar values received from the sale of farm products increased from 361.6 million in 1949 to 433.4 million in 1959 (adjusted to the 1959 value of the dollar). Approximately 65 percent of the dollar returns has come from the sale of crops. Farm consolidation, intensified crop production, and increased farm technology were primarily responsible for the increasing farm income and decreasing farm employment and number of farms. [32,33,34/]

One of the more easily definable agricultural areas in the United States is the Red River Valley of North Dakota and Minnesota. The Valley, one of the largest masses of level land in the world, is the filled-in basin of glacial Lake Agassiz. The surface soils are black and heavy, ranging in depth from 10 to 20 inches. This highly productive land is well adapted to the raising of small grains, flaxseed, and such specialty crops as sugar beets, and potatoes.

A small amount of irrigation is practiced in the Red River of the North study area. In 1950, there were approximately 4,370 acres of irrigated land in the study area creating a requirement of about 8,740 acre-feet of water. The Minnesota portion of the study area requires 5,600 acre-feet irrigating about 2,800 acres, while the North Dakota portion irrigates about 1,570 acres requiring 3,140 acre-feet of water.

The International Souris-Red River Engineering Committee concluded that no major increases in irrigation of the Red River of the North study area will occur without importation of water, inasmuch as the present dependable water supply is insufficient to warrant appreciable expansion. [4]

The production of potatoes and sugar beets has been largely responsible for the location of a number of heavy water-using food processing industries in the study area. [35,53] To determine the present capacity and potential of these industries, a closer look at the production of these crops is essential.

Table No. V-1 shows the acreage and bushels of potatoes produced by subareas for the Red River of the North Basin study. 32.

Table No. VI-1

Potato Production 32/
1954 - 1959

Red River of the North Basin Study

	1954		1959	
	Acres	Bushels (000)	Acres	Bushels (000)
Subarea I	72,419	14,505	82,082	16,636
Subarea II	44,647	10,451	54,926	11,770
Subarea III	4,962	1,109	5,999	1,126
Subarea IV	4,338	854	4,035	739
Subarea V	16,572	3,456	15,301	2,900
Subarea VI	548	76	285	51
Subarea VII	2,873	501	1,867	331
Subarea VIII	2,001	281	2,567	416
Total	148,360	31,233	167,062	33,969

In 1954, the study area produced over 18 million hundred weight of potatoes. Production continued to increase to 20 million hundred weight in 1959 and 24 million hundredweight in 1963. This production ranked the study area as third in the nation as a region growing late potatoes; only Idaho and Maine exceeded this mark. Subareas I and II were the major potato producers in the study area, harvesting about 85 percent of the total production. Potato processing industries tend to locate where the raw products are produced.

One of the most profitable crops raised in the study area is sugar beets. Beets thrive, especially in the heavy black loam near the river. In 1963, Polk County, Minnesota, led the study area in beet production, followed by Clay County, Minnesota, harvesting 34.5 and 20.7 thousand acres, respectively.

In 1963, the Red River of the North study area had almost 120 thousand acres harvested in sugar beets. The yield per harvested acre usually ranged from 10 to 13 tons in the study area. The production of sugar beets is localized to some extent around the sugar refineries located in Subareas I, II and V. Table No. VI-2 shows sugar beet production by acres and tons produced for the Red River of the North subareas from 1958 through 1963 and the location of the existing sugar refineries. 36,38/

Authority for controlling domestic sugar supplies is vested in the Sugar Act. By rigidly controlling supplies, the United States Government aims to protect domestic sugar producers and consumers from large fluctuation in world sugar prices. Therefore, National programs are the vital determinants for the production of sugar beets.

Minerals

Mineral production in the Red River of the North Basin is limited to sand and gravel and stone. In 1961, the dollar value of mineral production for the study area was about 4.5 million dollars (adjusted to the 1959 value of the dollar). Subareas II and V have been responsible for the largest returns accounting for almost 3 million dollars. Construction in the major cities of Fargo, Moorhead, Grand Forks, East

Table No. VI-2

Sugar Beet Production 84,35/
1958 -1963
(Thousands of Tons)
Red River of the North Basin Study

Subarea	1958 Acres	1958 Tons	1959 Acres	1959 Tons	1960 Acres	1960 Tons	1961 Acres	1961 Tons	1962 Acres	1962 Tons	1963 Acres	1963 Tons
I*	24,150	264.7	21,540	263.5	27,550	355.6	28,450	340.4	35,900	345.2	31,075	430.5
II**	36,200	469.9	35,950	486.1	40,060	550.5	42,675	579.0	51,600	462.4	44,330	597.0
III	4,250	53.8	4,500	53.1	4,970	61.7	5,800	67.3	6,800	68.0	6,550	85.2
IV	5,300	64.1	5,100	59.7	5,700	75.8	6,500	76.7	6,200	63.2	6,900	100.0
V***	21,700	238.7	21,620	228.3	24,015	290.6	26,075	337.2	21,710	202.2	27,130	382.4
VI	–	–	–	–	–	–	–	–	–	–	–	–
VII	830	9.1	960	10.2	1,125	13.0	3,105	37.3	1,600	11.8	2,700	32.5
VIII	–	–	–	–	–	–	–	–	–	–	–	–
TOTAL	92,430	1,100.3	89,670	1,100.9	103,420	1,347.2	112,605	1,437.9	123,810	1,152.8	118,680	1,627.6

* Refinery constructed; will begin operation in 1965
** Two Refineries
*** Refinery

Grand Forks, and Crookston has been primarily responsible for these returns.[39]

North Dakota has the largest deposits of lignite in the nation. However, these deposits are located west of the study area and should have no effect on the economy of the study area.

Employment in the mining category has been relatively insignificant, ranging from 70 in 1940 to 200 in 1960.[31]

Exhibit No. 6 depicts dollar values from mineral production by subareas.

Manufacturing

In 1960, the Red River of the North study area had about 10 thousand persons or five percent of the labor force employed in the manufacturing category. The number employed in this category has been increasing in actual numbers and in its proportion of the labor force since 1940. This employment increased from about six thousand in 1940, to about nine thousand in 1950 and to 10 thousand in 1960, representing three to four and five percent of the total labor force, respectively. Refer to Exhibit No. 4 for employment data.[31]

In 1960, the food and kindred products category employed about 50 percent of the total manufacturing employment. Fabricated metals, (including vehicles, machinery, transportation equipment, and other durables), and printing and publishing categories were the other major employers of the manufacturing category, employing 19 and 18 percent of the manufacturing employment, respectively. Other categories were relatively insignificant.[31]

The economics of location favor locating food processing plants near or in the area where the raw products are produced. Many of the agricultural products manufactured in the area, especially potatoes and sugar beets, are bulky and have a relatively high water content. Therefore, the location of these plants near the area of production resulted in less handling and transportation charges. 60/

In 1963, there were three sugar beet refineries in the study area processing approximately 1.5 million tons of sugar beets per year. Another refinery has been constructed and will begin operations in the fall of 1965. These refineries are presently operating from about October to February and are located in Subareas I, II and V.

In 1962, there were 12 potato processing plants located in the study area. These plants manufacture frozen french fries, dehydrated mashed potatoes, potato starch, potato flour, and potato chips. Only 12 percent of the total potato production was processed in the study area. Twenty-one percent was shipped out of the area for potato chips processing and the remaining 67 percent was for fresh and tablestock use. These plants are located primarily in Subareas I, II, and V and operate from about October through May.

In 1964, there were five turkey processing plants located in the study area. These plants process a total of about 1.8 million chickens and turkeys from about August through December and are located in Subareas II, V, VI and VII.

Other manufacturing water uses are presently relatively insignificant in the study area.

Value added by manufacturers, which is generally considered to be the best value measure available for comparing the relative economic importance of manufacturing among the other industries, has shown an increase since 1947. Over 60 percent of the value added and the number of establishments was located in Subareas II and VII. Exhibit No. 7 depicts manufacturing trends for the study area. 47/

Population

Total population in the study area increased about 10 percent during the period 1910-1960, increasing from 521,254 in 1910 to 573,321 in 1960. During this period the rural sector decreased from 451,329 to 330,749, while the urban sector increased from 69,925 to 192,572. The most significant increases were in Subareas II and V. The municipalities of Grand Forks, East Grand Forks, Crookston, and Thief River Falls have been largely responsible for the population growth in Subarea II, while the Fargo and Moorhead (SMSA) has been largely responsible for the population growth in Subarea V. Other subareas have had insignificant growth or lost population during this period. The decrease in agricultural employment has been primarily responsible for this decrease. Refer to Exhibit No. 8 for population data. 42/

Future

An analysis of the employment and natural resources situation and using a number of Federal, State and local studies as guides, the population and employment projections, as shown in Exhibits No. 4 and 8 were determined.

The projected population and employment rate of growth for the study area is projected to be less than that of the United States. The primary reasons are the somewhat isolated location and lack of abundant known natural resources of economic value in the area.

Agriculture

While the economy of the study area is expected to change into a more balanced industrial-agricultural nature, it is expected to remain predominately agricultural. Agricultural employment will continue to make up the largest portion of the basic labor force. Technological and other changes will continue to occur within the agricultural economy so that larger farms will be operated by a smaller agricultural labor force.

Crops, due to the high productive capacity of the soil in the study area, will continue to be the largest producer of farm income, although livestock production should become increasingly important.

Sugar beet acreage is expected to increase to 170 thousand acres in 1965 to help supply the new refineries in Subarea I. To support the existing and projected refineries, there is adequate acreage available in the study area.

To meet future regional and national demands, approximately 380 thousand acres of sugar beets are projected to be in production by 2015. This projection was based on present acreage and increased national demands.

The farm labor force is expected to continue decreasing, however at a slower rate and its proportion of the total labor force reaching 19 percent or 49,500 employees by 2015. 44,45,51,52,55/

Mining

The extraction of sand and gravel and stone in the study area is expected to be the only mining activity in the future. Employment in this category is expected to have a moderate increase reaching about 500 in 2015. This employment is expected to be centered around the larger municipalities in Subareas II, V, and VII, where construction will utilize these minerals.

Manufacturing

In 2015, the processing of food and kindred products is anticipated to form the largest part of the manufacturing category, employing about 35 percent of the labor force. Fabricated metals (including machinery, vehicles, transportation equipment, and other durables) and printing and publishing are projected to make up 30 and 20 percent of the manufacturing employment.

Sugar beet refining, as part of the food and kindred products category, is projected to increase. In addition to the refineries presently located in Subareas I, II, and V, another refinery is projected to locate in the vicinity of Subarea VII. Sugar companies and railroads have shown an interest in the location of a sugar refinery in Subarea VII. The local people have recently passed a bond issue to aid in financing the construction of a refinery. The presence of a sugar beet association in that vicinity, as well as other favorable economic factors presents strong indications of a refinery in that subarea. 40/

Wide fluctuations of sugar imports, because of world political and economic situations, make it hazardous to project sugar beet refining in a given area. Therefore, projections are based on national demands for sugar. Production in these refineries is projected to increase to process about 38,000 tons of sugar beets per day by 2015. Production in the newer refineries in Subareas I and VII are projected to increase at a higher rate and produce about half of the total production by 2015. These refineries are expected to increase operation to about 5 months or 150 days.

The demand for potato flakes, potato chips, frozen french fried potatoes, and dehydrated potatoes is expected to increase in the future. Past trends have shown significant increases in potato processing. However, adjusted to future national demands, processing of potatoes in the study area is projected to increase about 70 percent by 2015. Subareas I, II, and V are expected to have the major portion of these increases. 56/

The poultry processing industries are projected to have moderate increases. The Red River of the North Basin is located slightly west of the highly developed chicken and turkey raising area. Increases in processing of this product can be expected to extend into Subareas II and VII. These industries are expected to increase about 25 percent by 2015, corresponding with the population increase.

Other manufacturing increases which could create a demand for water are relatively insignificant.

Services

A greater proportion of the labor force is projected to be employed in the dependent industries (including construction, transportation, communication, utilities, retail and wholesale trade, public administration, and personal services) in 2015 than in 1960. A greater demand for the services caused by a higher standard of living will be the primary reason for this increase.

Population

A number of local, state and federal agencies have conducted extensive economic and demographic studies* in the Red River of the North study area. Utilizing these studies as a guide and analyzing the employment and natural resource situation, the Red River of the North study area population is projected to increase from a 1960 base of 573,321 to 760,000 in 2015. During this period the urban sector should continue to increase from 192,000 to 550,000, while the rural sector should continue to decrease from 381,000 to 210,000. Subarea V, (Fargo-Moorhead Standard Metropolitan Statistical Area) is expected to have the most significant growth, increasing from 106,000 in 1960 to 220,000 in 2015. 46/

Subarea II is also projected to increase at a rapid rate, from 135,000 in 1960 to 210,000 in 2015. The larger cities of Grand Forks, East Grand Forks, Crookston, and Thief River Falls are projected to get the largest portion of this growth. 43/

The remaining subareas are projected to have relatively insignificant growth or a decreasing population. 48,49/ Exhibit No. 8 details subarea projections.

---

* Bibliography numbers 43,46,47,48,49,50,54,57,58,59,62, 80

VII. MUNICIPAL AND INDUSTRIAL WATER SUPPLY

Historic Municipal and Industrial Water Use

Most of the small municipalities in the study area use ground water. The principal communities of Wahpeton-Breckenridge, Fargo-Moorhead, Grand Forks-East Grand Forks, Crookston, Grafton, Thief River Falls, and Fergus Falls use surface water. The Fargo-Moorhead metropolitan area has developed ground water yields of approximately 5.5 mgd and obtains part of its water supply from this source. The combined water use of the above listed communities represents the major surface water demand in the study area. The smaller communities using surface water in the study area are: Hallock, Oslo, Stephen, and Frazee, Minnesota and Cavalier, Drayton, Neche, Pembina, Grafton, Park River, Mayville, and Casselton, North Dakota. The source and average output of all municipal water systems in the study area are shown in Exhibit No. 2.

Most of the small industrial plants in the study area have their own wells or obtain water from a municipal system. The sugar beet, potato, and poultry processing plants constitute the major industrial water requirements in the study area. The slaughterhouses and milk processing plants are significant water users in some communities. Present amounts of water used by the major water-using industrial plants in the study area are estimated from information obtained during field investigations and are shown in Table No. VII-1.

Table No. VII-1

Present Major Industrial Water Requirements and Waste Loadings

Red River of the North Basin Study

Subarea	Trading Center	Industry	Water Requirements (mgd)	Raw Waste Loading 5-day BOD (1000#/day)
I	Grafton	Potato Processing	0.8	12.
II	Grand Forks- E. Grand Forks	Potato Processing Sugar Beet Processing	1.1 4.	12, 16.
	Crookston	Potato Processing Sugar Beet Processing	0.2 4.	2. 16.
	Foston	Potato Processing	0.2	3.
	Thief River Falls	Turkey Processing	0.1	0.5
V	Barnesville	Potato Processing	0.2	4.
	Fargo-Moorhead	Sugar Beet Processing	4.	16.
VI	Valley City	Turkey Processing	0.1	0.3
VII	Pelican Rapids	Turkey Processing	0.3	1.
	Detroit Lakes	Turkey Processing	0.3	1.
	Frazee	Turkey Processing	0.2	0.6

Potato, turkey and sugar beet processing are done on a seasonal basis. The above water requirements are: October through May for potato processing, August through December for turkey processing, October through January for sugar beet processing.

Projected Municipal and Industrial Water Requirements

Municipal water requirements include residential, public, commercial and those industrial uses which can reasonably be reflected as a function of municipal population - gallons per capita day (gpcd). Future municipal water requirements are based on projected population shown in the Economic Section (VI) and on municipal per capita water requirements. Water-use data on various municipalities in the study area were collected and analyzed to develop the 1965 data in Table No. VII-2.

Table No. VII-2

Municipal Water Requirements Per Capita
(gpcd)

Red River of the North Basin Study

Region	Year 1965	 2015
East of 10 inch net loss line	90	115
Between 10 and 12 inch net loss line	85	110
West of 12 inch net loss line	70	95

See Exhibit No. 9 for information on the development of Table No. VII-2.

Industrial water requirements are defined as those large water-using industries whose requirements can significantly effect the total water demands in an area. In this study the industrial water requirements of the sugar beet, potato, poultry, and milk processing plants and the slaughterhouses are projected separately from the municipal water requirements. These plants are part of the food and kindred products industry which is one of the seven principal water-using industries.

Projections of industrial water requirements can be based on either of two factors: 1) Water use per unit of product, or 2) water use per employee. Most of the water requirements and waste loading information available on industry in the study area is based on units of production and this was used as the basis for projecting water requirements.

The pounds of turkeys processed, employment, and limited water use data for four plants in the study area were determined from a 1960 survey made by the Minnesota Department of Health and from field investigations. Turkey processing is estimated to require 35,000 gallons of water and to discharge 128 lbs. of 5-day BOD per 1,000 birds. 65,68/ Based on employment figures for plants in the basin, turkey processing is calculated to require 1,600 gallons of water and to discharge 6 lbs. of BOD per day per employee.

The pounds of product or milk equivalent, processes used, water use, and employment data are available on 30 plants in the study area from a 1960 survey by the Minnesota Department of Health. The quantities of BOD in various dairy process wastes are taken from the literature. [67] The typical milk process plant in the study area requires 1,600 gallons of water and discharges 5 lbs. of 5-day BOD per day per employee.

The number and type of animals, the number of employees, and the water use for eight small slaughterhouses in the study are available from a 1960 Minnesota Department of Health Survey. The water requirement and waste loading for slaughterhouses are found in the literature. [66,69] Nationwide slaughterhouse water requirements per employee are considerably higher than those reported in the 1960 Minnesota survey for small parttime slaughterhouses in the study area. The typical combined slaughterhouse-locker plant in the study area requires 200 gallons of water and discharges 2.5 lbs. of 5-day BOD per day per employee.

There are 10 potato processing plants in the study area with large water requirements. Two of these plants are not being operated at the present time. Water requirement and waste loading data were obtained from the North Dakota and Minnesota Health Departments. The amount of raw material processed, the type of process and the characteristics of the waste water have been published for some of the plants in the study area. 70,71,72,73/

The water requirements and strength of the waste discharges by type of finished product have been developed from available information on plants in the study area and are presented in Table No. VII-3.

Table No. VII-3

Potato Processing Water Requirements and Waste Strength

Red River of the North Basin Study

Finished Product	Water Requirement (Gallons/Ton)	Waste Strength 5-day BOD (mg/1)
Flakes	5,000	1,700
Starch	1,100	2,000
Frozen	1,700	1,500
Flour	1,700	1,500

The four sugar beet refineries in the study area are located at Drayton, East Grand Forks, Moorhead and Crookston. The Drayton plant, which is at present under construction, is scheduled to begin processing in the fall of 1965. The water requirements, waste characteristics, and capacity of the refineries were determined from Minnesota Department of Health's records [74,75], from contacts with the American Crystal Sugar Company, and from a PHS stream survey made in 1964-65.

In 1949-51, a study established a water requirement of 2,000 gallons per ton with 90 percent return flow. The recent PHS stream survey measured water-use at the beet sugar plants of about 4 mgd. The plants were processing about 4000 tons of beet/day, resulting in a water use of 1000 gallons per ton. Minor adjustments are made in these figures to account for difference between refineries.

The 2015 municipal water requirements are computed from the developed water-use data and the 2015 population projections. The 2015 industrial water requirements are computed from the developed water-use data and the 2015 employment or production projections. The population, employment, and production projections are given by subareas in Section VI. The subareas' boundaries were established insofar as possible to include all of one or more subbasins. Subarea projections are proportioned among the trading centers in the subarea to locate the water supply requirements.

Projected 2015 water requirements for trading centers with significant municipal and industrial water demands are shown in Table No. VII-4. The industrial water requirements in Table No. VII-4 are projected by type of good material processed, i.e., sugar beets, (S.B.) potatoes (Po.) and slaughterhouse, turkeys, milk (S.T.M.)

Industrial water requirements for slaughterhouses and/or milk processing plants, which total less than 0.02 mgd, are accounted for in the municipal water requirements. The total water requirements shown in Table No. VII-4 are a sum of the municipal and industrial requirements for each trading center. The monthly distribution of municipal and industrial water requirements is different. To determine the monthly municipal and industrial water requirements, they are distributed separately by months and then summed.

Provision for Municipal and Industrial Supplies

Because of the minimum practical reservoir release and high transmission losses in the basin, continuous streamflows cannot be maintained at the lower requirement levels shown in Table No. VII-4. In fact, releases from Homme Reservoir on the Park River of 1.3 mgd or less are entirely lost in transmission. In general it is considered practical to plan continuous streamflow for water supply only on a whole mgd basis. At present slug releases from Homme Reservoir are being made in intervals of several days and being stored behind the low-head dams necessary for operation of a water intake structure. Those trading centers with small water requirements which purchase reservoir storage are expected to use a slug release pattern to minimize their storage cost.

Most of the trading centers with projected 2015 municipal and industrial water requirements have at present a ground water source. With few exceptions ground waters in the North Dakota portion of the study area have high concentrations of TDS and/or SO_4. 79/ Either or both of these constituents will usually exceed the maximum limits set forth in the 1962 Public Health Service Drinking

Table No. VII-4

2015 Municipal and Industrial Water Requirements

Red River of the North Basin Study

(MGD)

Subarea	Trading Center	Municipal	Industrial S.B.	Industrial Po.	Industrial S.T.M.	Total
I	Cavalier	.24			.03	.27
	Drayton	.20	10.		.03	10.23
	Walhalla	.23			.03	.26
	Neche	.43				.43
	Pembina	.17				.17
	Langdon	.38			.03	.41
	Grafton	1.26		1.06	.04	2.36
	Park River	.24			.03	.27
	Roseau	.46			.12	.58
	Hallock	.26				.26
	Greenbush	.16				.16
	Argyle	.16				.16
	Stephen	.16				.16
	Warren	.34				.34
II	Larimore	.24			.08	.32
	Red Lake Falls	.29				.29
	Thief River Falls	2.30			.29	2.59
	Bagley	.23			.03	.26
	Crookston	2.75	6.	.35	.05	9.15
	Fosston	.29		.34	.30	.93
	McIntosh	.17			.02	.19
	Grand Forks-East Grand Forks	13.20	8.	2.20	.10	23.50
	Northwood	.20				.20
	Fertile	.17			.02	.19
III	Finley	.20				.20
	Hatton	.20				.20
	Hillsboro	.44			.05	.49
	Mayville-Portland	.95			.06	1.01
IV	Mahnomen	.28			.05	.33
	Twin Valley	.23			.03	.26
	Ada	.55			.03	.58
IV	Halstad	.24				.24
V	Fargo-Moorhead	16.50	6.		1.00	23.50
	Barnesville	1.10		.57		1.67
	Hawley	.88			.02	.90
	Casselton	.77				.77
	Kindred	.38				.38
VI	Valley City	1.23			.32	1.55
	Cooperstown	.23			.03	.26
	Harvey	.38			.10	.48
	Enderlin	.23				.23
	Lisbon	.28			.03	.31
VII	Hankinson	.17			.04	.21
	Lidgerwood	.17				.17
	Wahpeton-Breckenridge	2.31	10.		.02	12.33
	Fergus Falls	2.20			.75	2.95
	New York Mills	.16			.02	.18
	Pelican Rapids	.33			.77	1.00
	Perham	.40			.10	.50
	Detroit Lakes	1.26			.80	2.06
	Frazee	.23			.30	.53
	Elbow Lake	.26				.26
	Herman	.17				.17
	Wheaton	.38				.38
	Lake Park	.15			.03	.18
VIII	Cando	.29			.06	.35
	Rolla	.19			.06	.25
	Rugby	.66			.06	.72
	Devils Lake	1.33			.07	1.40
	Lakota	.19			.08	.27
	Maddock	.14			.05	.19
	McVille	.14			.05	.19

Water Standards. [63/] These ground waters also contain high concentrations of bicarbonate hardness (HCO_3). In many cases where SO_4 concentrations are less than 250 mg/1, a satisfactory water quality could be obtained by reducing the concentrations of TDS through precipitation of the bicarbonate ion with the conventional lime softening process.

The limited water quality data on the west bank tributaries are presented in Table No. V-3. These data indicate that during a large part of the year the quality of the surface water from the west bank tributaries exceeds the maximum limits [63/] of TDS and/or SO_4.

At a few North Dakota trading centers, the municipal and industrial water requirements are supplied by a ground water with a mineral concentration which is higher than that of the nearest surface water source. However, the mineral concentration of the surface water exceeds the maximum limits [63/] for TDS and/or SO_4. Using a surface water source will increase the capital and operation costs of treatment facilities. Where the ground water is being depleted and the surface water is of good quality the trading centers are expected to use the surface source in the future. The Fargo area is an example of this trend.

Subbasin Municipal and Industrial Water Needs and Existing Sources

To meet the 2015 municipal and industrial water requirements shown in Table No. VII-4, it may be desirable to provide storage in the projects under consideration. Many of these requirements can be met by presently developed ground water sources and/or dependable streamflow. In accord with the Inter-Service Supply Support Agreement, these water requirements and storage needs are discussed for the Red River and principal tributaries. The study area is grouped by basins as follows: Pembina and Tongue Rivers Basin, Upper Sheyenne River Basin, Lower Sheyenne River Basin, Wild Rice River Basin (North Dakota), Devil's Lake Basin, Roseau River Basin, Two River Basin, Snake and Tamarac Rivers Basins, Red Lake River Basin, Sand Hill and Marsh Rivers Basins, Wild Rice River Basin (Minnesota), Bois de Sioux River Basin, and the main stem of the Red River of the North.

Municipal and industrial water storage needs are computed at a 98 percent protection level, represented by a 0.02 probability of flows being equal to or less than that for which protection is provided.

Pembina and Tongue Rivers Basin

The 2015 municipal and industrial water requirements of significance in the basin are located at the trading centers of Walhalla, Langdon, Neche, Cavalier, and Pembina.

Walhalla obtains its water from shallow sand and gravel deposits in the valley of the Pembina River. In 1961 the yield from the wells decreased, and the city increased the yield by damming up the river to recharge the aquifer through percolation. Although the rate at which water can be withdrawn from a well has not been determined, the valley deposits probably constitute the most extensive and productive aquifer in the area.[81/] The city has recently put a new well in operation which yields a million gallons per month and has abandoned one of the two old wells. Investigation around Walhalla shows that moderate to large supplies of ground water may be present in aquifers in and underlying the McCanleyville and Cambell beaches, in the Pembina delta and in deposits in the valley of the Pembina River.[81/] A more comprehensive study would be necessary to determine the yields of these aquifers. [81/]

which yields a million gallons per month and has abandoned one of the two old wells. Investigation around Walhalla shows that moderate to large supplies of ground water may be present in aquifers in and underlying the McCanleyville and Cambell beaches, in the Pembina delta and in deposits in the valley of the Pembina River. 81/ A more comprehensive study would be necessary to determine the yields of these aquifers. 81/ Walhalla is on the eastern edge of the Pembina delta which consists of broad elevated tracts of sand and smaller amounts of gravel. Wells tapping this deposit may each yield as much as 200 gallons per minute (gpm). 87/ Walhalla can continue meeting its municipal and industrial water requirements to 2015 from developed and known ground water sources with little additional capital investment.

Langdon is expected to continue to obtain their water supply from the ground and surface sources in the general area, 21/ and will not need water storage to meet municipal and industrial requirements at least to 2015.

Neche and Pembina use the Bembina River as their source of supply. Cavalier uses the Tongue River and ground water as its sources of supply. Ground water aquifers in the beach ridges and buried deposits could be developed as sources of supply for these trading centers. 18/ Based on the presently developed ground water sources, natural runoff, and projected conditions, Neche, Pembina, and Cavalier are expected to need water storage to meet future municipal and industrial requirements. In critical years storage releases will be needed during January and February at Neche and Pembina and from August through March at Cavalier. By 2015 the needed annual yield from storage will be 0.02, 0.02, and 0.05

mgd for Neche, Pembina, and Cavalier, respectively. The year of first need is 1980 for the three trading centers.

Park River Basin

The significant 2015 municipal and industrial water requirements in the basin are located at Park River and Grafton. The Geological Survey has no knowledge of large ground water aquifers in the basin.[18] Thirteen test holes were drilled near Minto and nine near Forest River in an attempt to find an aquifer that would be suitable for a municipal supply for the city of Grafton, but no aquifer large enough to yield a municipal supply was found.[92] Based on the natural runoff below Homme Reservoir and projected conditions by 2015, the needed annual yield from storage at Park River and Grafton will be 0.06 and 0.9 mgd, respectively. With releases from the allocated storage in Homme Reservoir, the 2015 M&I requirements at Park River can be met or exceeded at the 98 percent protection level and about 70 percent of the 2015 M&I requirements at Grafton can be met.[97] By the year 1990, additional storage will be needed to meet the M&I requirements at Grafton. By the year 2015, the annual yield from additional storage needed at Grafton will be 0.4 mgd. In critical years storage releases will be needed from August through March.

Forest and Turtle Rivers Basins

These two adjacent basins contain 1700 square miles of area, between the Park and Goose Rivers. There are four municipalities in the basins with a municipal water system and/or a waste collection system. Two of these communities have no municipal water system. The projected water requirements have been grouped into a service area centered at Larimore. Larimore presently has by far the largest water demands and a ground water yields that exceed the basin's 2015 municipal and industrial water requirements. The Elk Valley delta is partially located in these two basins. Wells tapping this extensive aquifer may yield as much as 200 gpm. [87] Several municipalities in the basins, including Larimore, are within the boundaries of the Elk Valley delta.

Based on presently developed and available ground water sources and projected conditions, no water storage needs for municipal and industrial purposes are expected by 2015.

Goose River Basin

The significant 2015 municipal and industrial water requirements in the basin are located at Hillsboro, Mayville-Portland, Hatton, Northwood, and Finley.

All domestic and municipal water supplies in the Goose River Basin, with the exception of Mayville, depend entirely on ground water for their source of supply. [88] The developed ground water sources consist of the river alluvium, the Elk Valley delta, the Dakota sandstone, beach ridges and buried glacial deposits. In the Portland area local developments on the order of 0.5 to 1.0 mgd could be maintained for many years from the Dakota sandstone. [78] There are eleven known beach ridge aquifers in the basin. [78] Many of these should be able to develop yields of 0.5 mgd or more. [18] Properly spaced wells in the Hillsboro aquifer would sustain yields of approximately 100 gpm each. [76] Wells tapping the Elk Valley Delta deposits may yield as much as 200 gpm. [87] The available data [25,26,76,78,79] show that both the developed ground waters and the surface water have concentrations of Cl, SO_4 and TDS of which one or more exceed the upper limits of the 1962 Public Health Service Drinking Water Standards.

Hatton is presently developing additional known ground water sources. The other Trading Centers have sufficient water supplies and known abundant additional ground water sources. Based on projected conditions, developed and available ground water [18,76,77,78] the need for surface water storage for municipal and industrial purposes is not expected by 2015.

Upper Sheyenne River Basin

The Upper Sheyenne River Basin is defined as that portion of the basin above the planned canal connecting the Sheyenne River to the Red River above Fargo. The significant 2015 municipal and industrial water requirements in the basin are located at Valley City, Harvey, Kindred, Lisbon, Maddock, McVille, and Cooperstown.

Two known extensive ground water aquifers located in the basin are (1) a deposit of unconsolidated clay, silt, sand and gravel located along the Sheyenne River Valley from about Maddock to Lisbon, and (2) the Sheyenne delta, a large sand deposit, extending from Lisbon to near Kindred. Large supplies of ground water may be obtained from the alluvial gravel deposits of the Sheyenne River Valley, [87,92] The water bearing sand and gravel deposits are generally at depths of less than 100 feet. Maddock has developed a ground water source in these alluvial deposits in the Big Coulee Valley, 2 miles west of the city. Tests on the city well indicate that the aquifer is quite permeable and should yield water readily.[92] Both Valley City and Cooperstown have developed ground water in terrace deposits along the river valley. At Valley City investigations show that the aquifer is being artificially and naturally recharged by the river. All of the above trading centers, except Harvey, are located on or near these aquifers. The maximum dependable draft of the developed ground water exceeds the 2015 municipal and industrial requirement at all the trading centers except Kindred. The Sheyenne Delta contributes to the base flow of the Sheyenne above Kindred. There is an average gain of 28.8 second-feet in the Sheyenne River from the Sheyenne delta aquifer. 89/ Based on projected conditions, developed ground and available water sources, and recharge from streamflow, storage of water is not expected to be needed to meet 2015 municipal and industrial requirements in the Upper Sheyenne River Basin.

Lower Sheyenne River Basin

The Lower Sheyenne River Basin is defined as that portion of the basin below the planned canal which consists mainly of the Maple River Basin. The significant 2015 municipal and industrial requirements in the basin are located at Casselton and Enderlin. Casselton has developed wells which reportedly tap the Dakota sandstone and has constructed a municipal reservoir on Swan Creek. The Maple Ridge aquifer is five miles east of Casselton and offers good opportunity for additional ground water supply. 90/ Both trading centers have developed ground water supplies with maximum dependable drafts that exceed their 2015 municipal and industrial requirements.

Based on projected conditions, developed and available ground water, natural streamflow, and present municipal water storage, additional water storage is not expected to be needed to meet 2015 municipal and industrial requirements in the Lower Sheyenne River Basin.

Wild Rice River Basin, North Dakota

Hankinson and Lidgerwood are the trading centers at which the significant 2015 municipal and industrial water requirements in the basin are located. Two known large ground water aquifers in the basin are the Sheyenne Delta and a gravel deposit in Sargent and Richland Counties near Lidgerwood. 18/ Transmission distance to the trading centers from the Sheyenne Delta is less than from the Wild Rice River. The available data 25,26,79/ show that both the developed ground water and the surface water have concentrations of TDS which exceed the maximum recommended limits in the 1962 Public Health Service Drinking Water Standards. Based on projected conditions and developed and available ground water sources, water storage is not expected to be needed to meet 2015 municipal and industrial requirements in the Wild Rice River Basin.

Devils Lake Basin

The Devils Lake area is a closed basin between the Red River of the North and the Souris River. The Devils Lake area formerly drained into the Red River and is considered a non-contributing area in the Red River of the North drainage basin.

The significant 2015 municipal and industrial water requirements are located at Devils Lake, Cando, Lakota, Rolla, and Rugby. The location of these trading centers can be seen on the Area Map. The maximum dependable drafts of the developed ground water exceed the 2015 municipal and industrial requirement at all trading centers except Rugby.

In 1964 Rugby's four municipal wells could deliver 0.5 mgd. 18/ However, the average concentration of TDS and SO_4 are in excess of 1500 and 1000 mg/l, respectively. 79/ Recent test drilling around Rugby have located five additional aquifers, two which contain water of good quality. 18/ At present, Rugby is planning on developing the closer of these aquifers which contained water with a concentration of 357 mg/l TDS. Besides these aquifers, the Pleasant Lake area which is 6 to 7 miles east of town, contains sand and gravel deposits which are believed to contain a plentiful supply of water. 18/

Based on projected conditions, developed and available ground water sources the need for storage to meet 2015 municipal and industrial water requirements in the Devils Lake Basin is not expected.

Roseau River Basin

The significant 2015 municipal and industrial water requirements in that portion of the basin within the United States are located at the trading center of Roseau. The present wells at Roseau can produce more than the expected 2015 municipal and industrial requirements. Based on projected conditions and developed ground water sources, the need for water storage to meet 2015 municipal and industrial requirements in that portion of the Roseau River Basin within the United States is not expected.

Two Rivers Basin

The significant 2015 municipal and industrial water requirements in the basin are located at Hallock and Greenbush. Hallock uses the South Branch of the Two Rivers as a source of supply. The natural runoff from the drainage area upstream from Hallock does not meet present needs. Water is presently released from Lake Branson to meet these needs. Lake Branson is a state owned and operated reservoir upstream from Hallock. Greenbush uses ground water as a source of supply. The four wells at Greenbush which can produce a total of about 0.5 mgd deliver a good quality water. 18/ This yield exceeds the expected 2015 municipal and industrial requirements at Greenbush. The available data 18,24,27/ show the developed ground water at Greenbush and the surface water in Lake Branson and in the Two Rivers at Hallock to have concentrations of TDS, SO_4 and Cl which are less than the upper limits of the 1962 Public Health Service Drinking Water Standards. Based on the projected conditions, developed ground water sources, and natural streamflow, a need for water storage exists at Hallock; the other trading center in the basin is expected to continue satisfying its water requirements from ground water sources. The annual yield from storage needed at Hallock is expected to be 0.04 mgd by 2015. The year of first need is 1965. In critical years, releases from storage may be required in October, November, January and February.

Snake and Tamarac Rivers Basins

The significant 2015 municipal and industrial water requirements in the basins are located at Stephen, Argyle, and Warren.

The source of water supply at Stephen is the Tamarac River. Argyle and Warren which are in the Snake River Basin, use ground water sources. The yields of the wells at Warren and Argyle exceed their 2015 municipal and industrial water requirements.

The available data 18/ show the concentrations of TDS, SO_4 and Cl in the Tamarac River at Stephen and in the streams and developed aquifers at Argyle and Warren, to be less than the upper limits of the 1962 Public Health Service Drinking Water Standards.

In the Stephen Area ground water has been located in the buried Gladstone beach and glacioflurial deposits. Most of the deeper aquifers in the Stephen Area contain highly mineralized chloride water. 91/ A shallow aquifer located 4½ miles south of Stephen has 60 feet of fine sand at maximum depth with a water table 10 feet below the ground surface. This source is capable of meeting needs at Stephen and is the northern extent of the aquifer which is used by Argyle, Minnesota. The chemical quality of the water from different wells is greatly different. The concentration of SO_4, Cl, and TDS in the water at Argyle 24/ and at one test hole near Stephen, 18/ is less than the upper limits of the 1962 Public Health Service Drinking Water Standards, but from another test hole near Stephen 18/ the concentration of these constituents is far in excess of the upper limits.

Based on projected conditions and natural runoff, water needs exist at Stephen. Other trading centers are expected to satisfy their 2015 water requirements from developed ground water sources. The annual yield from storage needed by 2015 at Stephen is 0.04 mgd. The year of first need is 1965. In critical years releases from storage may be required from October through February.

Red Lake River Basin

In the Red Lake River Basin, are located the largest municipal and industrial water requirements outside of the main stem of the Red River. The significant 2015 municipal and industrial water requirements are located at the trading centers of Crookston, Red Lake Falls, Thief River

Falls, Fosston, Bagley, and McIntosh. Of these, only Crookston and Thief River Falls obtain their water supply from a surface water source, and several industries in these two trading centers have their own wells. The other trading centers have developed ground water yields which exceed their expected 2015 municipal and industrial requirements. The natural streamflow below the Red Lake exceeds the 2015 municipal and industrial water requirement at Thief River Falls. Based on projected conditions, and natural streamflow below the Red Lakes, water storage is needed for Crookston; other trading centers are expected to satisfy their 2015 water requirements from developed ground water sources and surface water sources. The annual yield from storage expected to be needed by 2015 at Crookston is 3.0 mgd. With releases from the allocated storage in the Red Lakes the 2015 M&I requirements at Crookston can be met or exceeded at the 98 percent protection level. 97/

Sand Hill and Marsh River Basins

Fertile and Ada are the trading centers at which the significant 2015 municipal and industrial water requirements in the basins are located. The yields of the present wells at Fertile and Ada exceed the municipal and industrial water requirements expected in 2015. Based on projected conditions and developed ground water sources, water storage needs are not expected by 2015 for municipal and industrial purposes.

Wild Rice River Basin (Minnesota)

Twin Valley and Mahnomen are the trading centers at which the significant 2015 municipal and industrial water requirements in the basin are located. The yield of the ground water supply at these two trading centers exceed the municipal and industrial water requirements expected in 2015. The prospects are good for developing additional ground water supply in this basin.

Based on projected conditions and developed and available ground water sources, water storage for municipal and industrial purposes is not expected by 2015.

Buffalo River Basin

The significant 2015 municipal and industrial water requirements in the basin are located at Barnesville, Hawley, and Lake Park. Municipal and industrial water supplies in the basin are developed exclusively from ground water aquifers. The typical concentration of iron in the raw water is 2.0 mg/l.[24/] Because of this high iron content, an iron bacteria, Crenathrix, is a serious problem in maintaining well yields. Present well yields at the trading centers meet the 2015 municipal and industrial requirements. However, Crenothrix has, in the past, caused decreases in well yields and required the drilling of a new well at Barnesville.[18/] New well construction or expenditures for well maintenance is expected to be continued to maintain yields because it will be less expensive than treatment of the available surface water.

Based on projected conditions, developed and available ground water, storage of water is not expected to be needed to meet 2015 municipal and industrial requirements.

Otter Tail River Basin

The significant 2015 municipal and industrial water requirements in the basin are located at Fergus Falls, Detroit Lakes, Pelican Rapids, Frazee, Perham, and New York Mills. Fergus Falls uses the Otter Tail River as a source of municipal supply. Ground waters are however available as the State Hospital has its own well. The other trading centers in the basin use ground water sources exclusively. The developed municipal ground waters have a high iron content at all the trading centers except Perham. Iron concentrations range from 1.5 to 4.2 mg/l. 24/ Well maintenance costs are generally high throughout the basin. The developed ground water yields exceed the 2015 municipal and industrial water requirements at all trading centers except Fergus Falls and Frazee, and the natural streamflow exceeds the expected 2015 municipal and industrial water requirements at these two locations. Based on projected conditions, developed ground water, and natural runoff, storage of water will not be needed to meet 2015 municipal and industrial requirements in the Otter Tail River Basin.

Bois de Sioux River Basin

The significant 2015 municipal and industrial water requirements in the basin are located at Wheaton, Elbow Lake, and Herman. These three trading centers are in the Muskinta River subbasin. The Muskinta River flows into Lake Traverse. Ground water sources are used for municipal supply in the basin. The developed ground water has high concentrations of SO_4 which exceed the upper limit. 63/ At Elbow Lake and Herman, the concentrations of TDS and SO_4 in the surface water exceed the upper limits. 63/ See Table No. V-3. The yields of the developed ground water at the three trading centers exceed their 2015 municipal and industrial water requirements. Based on projected conditions and developed ground water sources, a need for water storage to meet 2015 municipal and industrial requirements is not expected.

Main Stem of the Red River of the North

The significant 2015 municipal and industrial water requirements along the main stem are located at Wahpeton-Breckenridge, Fargo-Moorhead, Halstad, Grand Forks-East Grand Forks and Drayton. The Fargo-Moorhead trading center includes Fargo, Moorhead, South West Fargo, West Fargo, and Dilworth. The Grand Forks-East Grand Forks trading center also includes the Air Force Base.

All the trading centers, except Halstad, use a surface water source. At Halstad, the developed ground water yield exceeds their 2015 municipal and industrial water requirement. Ground water sources have been developed at the other trading centers, but the only large developed ground water aquifers are in the Fargo-Moorhead area.

Ground water pumpage in Fargo and Moorhead has increased from 3 MG in 1903 to 807 MG in 1947. [90] The total withdrawals from ground water in Cass County (Part of the Fargo SMSA) were inventoried in 1963 and amounted to 1.6 billion gallons of which about 35 percent was for municipal and industrial use. [18] In 1954 two of Moorhead's municipal wells could together deliver 5. mgd, [18] however, the maximum dependable draft was reported [15] as 4. mgd in 1963.

Ground water investigations have been made in a 360 square mile area surrounding Fargo and Moorhead. [90] Throughout the area, till and associated glaciofluvial deposits occur. The general extent and thickness of six principal aquifers of glaciofluvial origin have been incompletely determined, but have an estimated storage of 900 billion gallons. This storage could support large withdrawals for many years. It has been estimated that the rate of recharge to the glaciofluvial aquifers in the area was in the order of 1 mgd. The rate of recharge will be increased as the water level in the area is lowered, possibly to as much as 2 or 2½ mgd. The development of ground water for municipal and industrial purposes has been accompanied by a lowering of water levels and artesian pressures over the area investigated.

For the purpose of this study, ground water pumpage is estimated to continue at the present maximum dependable draft of 5.5 mgd in the Fargo-Moorhead trading center. Presently developed ground water yields are considered insignificant in meeting 2015 municipal and industrial water requirements at the Wahpeton-Breckenridge, Grand Forks-East Grand Forks and Drayton trading centers. Based on projected conditions, developed ground water, natural runoff below existing Federal reservoir, and releases of 3.23 and 1.94 mgd from Orwell Reservoir and Lake Ashtabula, respectively, additional water supply will be needed to meet 2015 municipal and industrial water requirements at Wahpeton-Breckenridge, Fargo-Moorhead, Grand Forks-East Grand Forks and Drayton. The annual yield from storage expected to be needed by 2015 are 6.8 2.2, 0.7 and 3.8 mgd at Wahpeton-Breckenridge, Fargo-Moorhead, Grand Forks-East Grand Forks and Drayton, respectively. With releases from the allocated storage in the present Corps of Engineers reservoirs, the 2015 M&I water requirements at Wahpeton-Breckenridge, Fargo-Moorhead, Grand Forks-East Grand Forks and Drayton can be met or exceeded at the 98 percent protection level. [97]

VIII. WATER QUALITY CONTROL

General

Under provisions of the Federal Water Pollution Control Act, (33 U.S.C. 466 et seq) in the survey or planning of a reservoir by any Federal agency, consideration must be given to the inclusion of storage for regulation of streamflow for the purpose of water quality control. The Law expressly states that any such storage and water releases shall not be provided as a substitute for adequate treatment or other methods of controlling wastes at their sources. In this study adequate treatment of municipal waste is defined as 90 percent reduction in BOD with sufficient capacity to provide storage for winter sewage flows. Exhibit No. 9 presents the justification for this definition. For separately discharging food processing wastes projected adequate treatment is considered for this study to be 90 percent reduction in BOD during fall open-water conditions with holding lagoons adequate to retain the remainder of the treated waste until ice breakup in the spring.

Discharge of wastes, even when treated to the maximum economically feasible and practical limit, will cause an unsatisfactory quality condition in receiving waters whose waste assimilation capacity is exceeded. This condition usually, but not always, occurs during periods of low flows and may be avoided by the addition of water to maintain flows at higher levels. Recognition must be given to the need for required flows in receiving streams if the water quality is to be maintained at acceptable levels.

An appraisal of the economy shows that the type of water uses expected in the basin include instream as well as withdrawal uses. The instream water uses include recreation, propagation of fish and wildlife and the aesthetic appeal of the stream. The withdrawal uses include domestic water supplies, industrial process water, cooling water and irrigation water. Where proper quality is not maintained, public health may be endangered and the possible economic benefits of its use may be foregone. In the study area the critical water quality objectives are those which will allow use of the stream for domestic and industrial water supply and for propagation of fish to develop without undue interference. The goals which are used to indicate satisfactory quality are concentrations of total dissolved solids (TDS), sulfates (SO_4), chlorides (Cl), and dissolved oxygen (DO). These goals are the bases for determining the need for storage to regulate streamflow for water quality control.

The maximum concentrations for TDS, SO_4, and Cl are those set forth in the 1962 Public Health Service Drinking Water Standards of not greater than 500, 250 and 250 mg/l, respectively. These maximum limits are not exceeded when more suitable water supplies can be made available. The importance of chloride, sulfate and dissolved solids as they affect water quality hinges upon their taste and laxative properties. There is evidence that excessive amounts of these constituents cause consumer reactions which may result in individual treatment or rejection of the supply. 63 /

The dissolved oxygen concentration in water is one index of water quality, and its distribution within a stream gives a measure of the relationship between the oxygen supply and its utilization within that system. In this study, a DO content of not less than 4.0 mg/l in the stream has been selected as the basis for analysis. This DO goal is designed to provide an essential part of a suitable environment for the propagation of fish life; to enhance the aesthetic values of the stream; to aid in the protection of the public health and welfare and the prevention of nuisance conditions; and to support the continued expansion of industrial development and population.

Considering the needs for water, the cost of providing this water and the severity of the penalty when the water quality objective is violated, a degree of protection of 90 percent, represented by a 10 percent probability of quality being equal to or less than the criteria within any year was used.

Waste Loadings

Basic data indicating the present sources of all municipal pollution of significance in the study area are given in Exhibit No. 3. Exhibit No. 3 is a tabulation of municipalities by river basins. The 1960 population, the estimated population sewered, the waste discharge location, the type of treatment and the population equivalents (P.E.) of the raw and discharged wastes are given for each municipality. The population equivalent is the number of persons who would produce a sewage load of the same measured characteristic (usually BOD) as is produced by the waste in question. The type of treatment listed for two-thirds of all the plants in the basin is a lagoon with a zero P.E. discharge. The present major industrial raw waste loadings are estimated from information obtained during field trips and are shown in Table No. VII-1.

The projected 2015 raw waste loads by trading centers are given in Table No. VIII-1. The waste loads are in

Table No. VIII-1

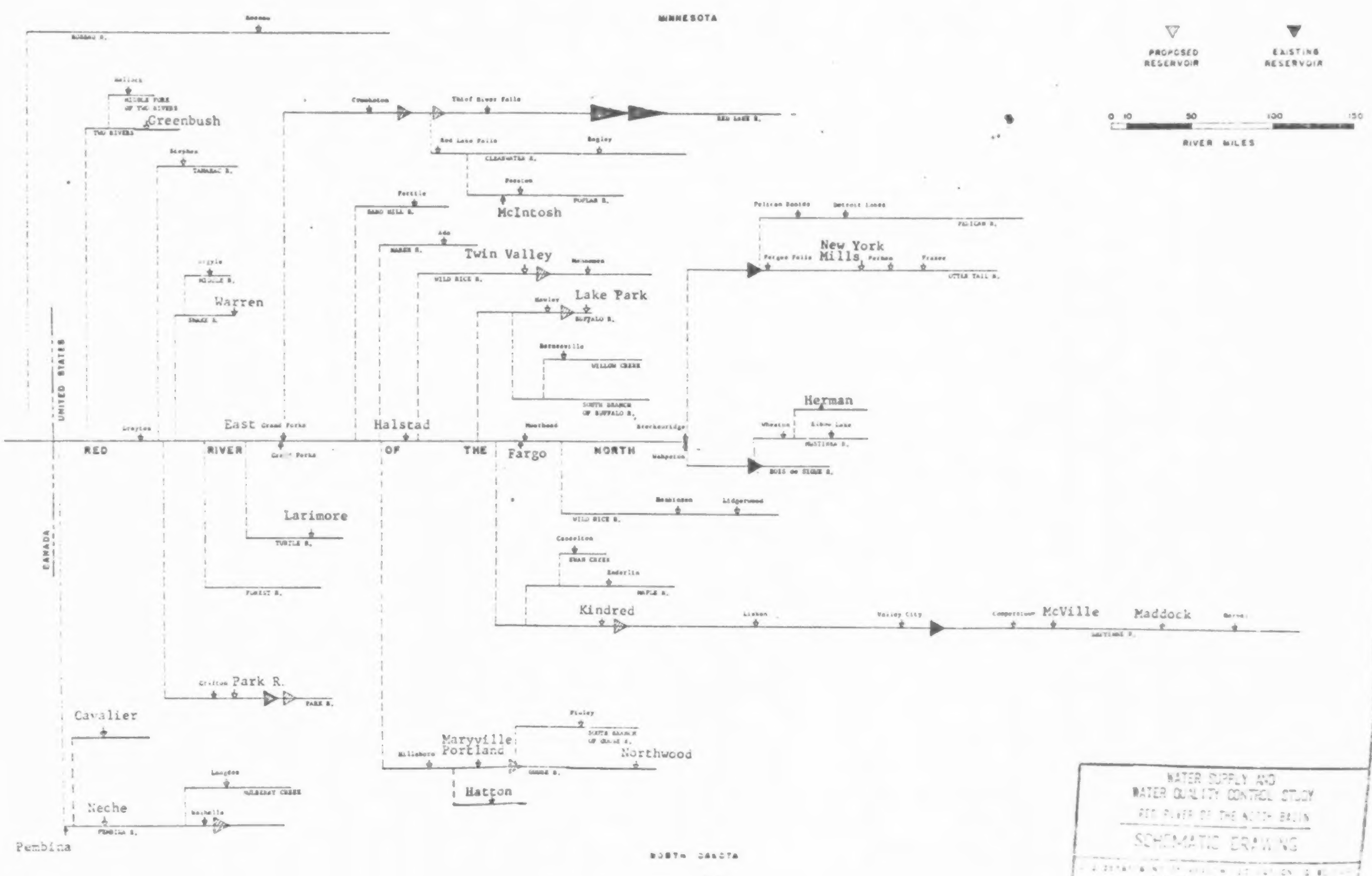
2015 Municipal and Industrial Waste Loadings-#BOD/Day

Red River of the North Basin Study

Subarea	Trading Center	Municipal	Industrial		
			S.B.	Po.	S.T.M.
I	Cavalier	550			70
	Drayton	450	59,000		70
	Walhalla	600			110
	Neche	250			
	Pembina	290			
	Langdon	1,000			110
	Grafton	2,900		20,000	100
	Park River	630			70
	Roseau	550			780
	Hallock	610			
	Greenbush	370			
	Argyle	360			
	Stephen	370			
	Warren	520			
II	Larimore	630			260
	Red Lake Falls	630			
	Thief River Falls	5,000			1,160
	Bagley	500			50
	Crookston	6,250	36,000	5,500	370
	Fosston	630		6,000	600
	McIntosh	380			50
	Grand Forks-East Grand Forks	28,700	36,000	34,000	800
	Northwood	530			
	Fertile	380			70
III	Finley	540			
	Hatton	540			
	Hillsboro	1,000			130
	Mayville-Portland	2,500			170
IV	Mahnomen	600			210
	Twin Valley	500			50
	Ada	1,250			120
IV	Halstad	540			
V	Fargo-Moorhead	37,500	36,000		4,800
	Barnesville	2,500		10,000	
	Hawley	2,000			100
	Casselton	2,050			
	Kindred	1,000			
VI	Valley City	3,200			1,200
	Cooperstown	600			140
	Harvey	1,000			780
	Enderlin	600			
	Lisbon	750			70
VII	Hankinson	400			80
	Lidgerwood	400			
	Wahpeton-Breckenridge	5,300	59,000		100
	Fergus Falls	5,000			3,700
	New York Mills	350			60
	Pelican Rapids	750			1,600
	Perham	880			310
	Detroit Lakes	2,750			2,200
	Frazee	500			1,000
	Elbow Lake	610			
	Herman	430			
	Wheaton	880			
	Lake Park	360			50
VIII	Cando	750			240
	Rolla	500			180
	Rugby	1,750			180
	Devils Lake	3,500			240
	Lakota	500			290
	Maddock	380			170
	McVille	380			170

pounds of BOD per day of ultimate carbonaceous demand. Most of the small industries in the basin produce little waste water. These small industrial wastes are grouped with the municipal waste load. Future municipal waste loads are computed from population projections and an ultimate BOD of 0.25 pounds per capita. The future industrial waste loads are computed from employment or production projections and from waste discharges which were developed from field investigations. The industrial waste loads in Table No. VIII-1 are projected by type of food material processed, i.e., sugar beets (S.B.), potatoes (Po.) and slaughterhouses, turkeys and milk (S.T.M.). The percent used in M&I Systems returning to the waste treatment plant and the waste discharge procedure used are described in Exhibit No. 9. The location of the trading-centers waste discharges to the river system is shown in Figure No. VIII-1, a schematic drawing.

The Garrison Diversion Unit, which will provide for irrigation of 250,000 acres and for restoration of Devils Lake, has been authorized by the Congress. A part of the drainage will be to the Red River of the North via the Sheyenne and Wild Rice Rivers of North Dakota. This Unit and its implications for water quality are described in detail in Exhibit No. 10.


MINNESOTA
NORTH DAKOTA
UNITED STATES
CANADA
PROPOSED RESERVOIR
EXISTING RESERVOIR
0 10 50 100 150
RIVER MILES
RED RIVER OF THE NORTH
Pembina
Drayton
East Grand Forks
Grand Forks
Halstad
Moorhead
Fargo
Breckenridge
Wahpeton
ROSEAU R.
Roseau
TWO RIVERS
MIDDLE FORK OF TWO RIVERS
Hallock
Greenbush
TAMARAC R.
Stephen
MIDDLE R.
Argyle
SNAKE R.
Warren
RED LAKE R.
Crookston
Thief River Falls
Red Lake Falls
CLEARWATER R.
Bagley
POPLAR R.
Fosston
McIntosh
SAND HILL R.
Fertile
MARSH R.
Ada
WILD RICE R.
Twin Valley
Mahnomen
BUFFALO R.
Hawley
Lake Park
WILLOW CREEK
Barnesville
SOUTH BRANCH OF BUFFALO R.
OTTER TAIL R.
Fergus Falls
New York Mills
Perham
Frazee
PELICAN R.
Pelican Rapids
Detroit Lakes
BOIS de SIOUX R.
MUSTINKA R.
Wheaton
Elbow Lake
Herman
WILD RICE R.
Hankinson
Lidgerwood
SWAN CREEK
Casselton
MAPLE R.
Enderlin
SHEYENNE R.
Kindred
Lisbon
Valley City
Cooperstown
McVille
Maddock
Harvey
GOOSE R.
Hillsboro
Mayville
Portland
Hatton
SOUTH BRANCH OF GOOSE R.
Finley
Northwood
TURTLE R.
Larimore
FOREST R.
PARK R.
Grafton
Park R.
PEMBINA R.
Cavalier
Neche
Walhalla
Langdon
HALBEDAY CREEK

WATER SUPPLY AND
WATER QUALITY CONTROL STUDY
RED RIVER OF THE NORTH BASIN

SCHEMATIC DRAWING

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
[illegible] KANSAS CITY, MO.

The peak irrigation return flows are estimated to usually result in August with the minimum return flows occurring in the late winter months. Estimated return flows, with full development of initial stage lands and without regulation in Baldhill Reservoir, will result in the following variations in accruals and capacities to the Red River: 82/

	Maximum	Average	Minimum
Annual Return Flows (Acre-feet)	79,000	66,000	55,000
Capacities (Cubic feet per second)	313	92	6

It is estimated that average annual return flows in the Red River Basin from the 250,000 acre project will occur as follows: 61/

Sheyenne River	45,000 acre-feet
Wild Rice River	21,000 acre-feet
Devil's Lake	7,000 acre-feet

Most of the return flow will have been used once for irrigation and would have increased in total dissolved solids. It is estimated that undiluted return flows will contain an average concentration of about 1,350 mg/1 TDS. 82/ This is exclusive of what effect flushing of Devil's Lake may have on quality of flows in the Sheyenne River.

Storage Requirements for Mineral Quality Control

Of the four quality goals, detailed calculations on TDS and DO were made to determine if water storage for quality control will be needed. The surface water quality data in Table No. V-3, with two exceptions, show the concentration of SO_4 and Cl to be presently at low levels. Future municipal and industrial use is not expected to raise the concentrations of these ions to levels that will damage water users in the Red River of the North Basin.

The concentrations of the TDS in most of the western tributaries (see Table No. V-3) frequently exceed the quality goal. Flow regulation for quality control is not recommended, however, because (1) the damages to water use are slight and (2) conventional water softening can reduce the TDS to acceptable levels.

The eastern tributaries generally are of better mineral quality than western tributaries. Present and projected water use is not expected to increase TDS concentrations above the quality criteria.

The limitations of available data preclude a precise analysis of the impact of the initial stage of the Garrison Diversion Unit (Exhibit 10) on water quality and flow regulation needs. However, general estimates, based primarily on average and/or expected concentrations and flows, as affected by irrigation, are presented for two cirtical water use points in the area--the Red River at Fargo-Moorhead and at Grand Forks-East Grand Forks.

The quality of the Red River at Fargo will be a blend of regulated and unregulated flows from the Red, Otter Tail, and Wild Rice Rivers plus irrigation return flows to the Wild Rice River. Often now the TDS concentration exceeds 500 mg/l (Tab. V-3). Because of this fact and the extreme variability of flows above Fargo, it is obvious that the existing flows have limited dependable potential for diluting the irrigation returns. Consequently, we recommend that storage be provided to negate the added impact of 75 percent of the maximum irrigation returns of 25,000 acre-feet via the Wild Rice River of North Dakota. This storage would necessarily be located on the Eastern tributaries because of their superior water quality.

The annual quantity of flow regulation required to meet TDS criteria at Fargo depends greatly on the TDS of the stored water in the following relations:

Concentration of Storage (TDS-mg/l)	Annual Draft on Storage (Acre-feet)
250	65,000
300	80,000
350	105,000

The very limited chemical data suggest that the 80,000 acre-feet of storage, corresponding to 300 mg/l, be used for preliminary planning purposes. This recommended storage may be in excess of that which can be developed feasibly in this geographic area.

At Grand Forks water plant intake the long-range average TDS concentration with the irrigation waters from the Sheyenne will be about 400 mg/l. However, concentrations greater than 500 mg/l would be expected frequently in late summer and fall when irrigation returns were high and the natural runoff is declining in volume and increasing in mineral concentration. Two alternative solutions to the Grand Forks problem are evaluated. The first would be to provide sufficient storage behind Kindred Dam to hold most of the combined natural mineralized and irrigation return inflows from about July or August to the spring breakup in March or April. This alternative would be quite effective but perhaps incompatible with the concepts of dual-use of storage space as commonly practiced in this region (see section V).

If retention in Kindred is used to control quality, approximately 60,000 acre-feet of storage space should be provided and allocated for water quality control. This estimate is based on holding 25 percent of an average annual runoff of 75,000 acre-feet plus 75 percent of the maximum annual irrigation return of 54,000 acre-feet.

The second alternative would be to exercise no control of the Sheyenne River for quality purposes but to dilute total Red River flows in excess of 500 mg/l with releases from storage provided for this purpose of eastern tributaries. Approximations of the annual draft-on-storage required for this alternative are less precise because of the inability at this time to simulate realistically the monthly or seasonal water quality spectra at Grand Forks.

On the basis of the best estimates for the various components of the water-quality system to be controlled, an annual draft-on-storage of 150,000 acre-feet from eastern tributary reservoirs is recommended for mineral quality control at Grand Forks. This recommendation for storage is based on maintaining 500 mg/l TDS on an average of 9 years out of 10 by diluting a mixture of 25 percent of the annual uncontrolled runoff (Table V-2) having an average concentration of 450 mg/l and 75 percent of the maximum annual irrigation return flow to the Red River via the Sheyenne River, that has an average concentration of 1,350 mg/l. The concentration of impounded eastern tributaries is approximated to be 300 mg/l, as in the computation of drafts-on-storage required above Fargo.

On the basis of quality control alone seasonal storage of salts in Kindred Reservoir (Alternative 1) would be more economical than diluting the total Red River above Grand Forks (Alternative 2). Consequently, alternative one is used in evaluating the quality control benefits. However, under the total water resource development plan for the Red River Basin, alternative two, involving increasing stream flow during low flow periods of the year, might be more compatible with other project purposes and incrementally least costly.

Flushing Devil's Lake: The water quality impact of the flushing of the Devils Lake system under the authorized Garrison Diversion Plan is not evaluated in this report. With the dearth of concrete information on proposed operating schemes, time schedules, and responses of stream quality, a detailed evaluation at this time would be folly. Nevertheless, preliminary computations with gross data indicate that flushing can be accomplished with maximum speed while incurring minimum water quality degradation in the Red River only through a closely controlled system of releases to the Sheyenne, holding and mixing in Lake Ashtabula and Kindred Reservoir, and maximum use of the diluting capabilities of uncontrolled flow to the Red River and of all releases from tributary reservoirs. To provide this necessary control will require detailed mathematical models for predicting stream quality response, a network for environmental monitoring and short-term predictions, and close coordination among all interested parties. The Missouri-Souris-Red River Basins Comprehensive Water Pollution Control Project will direct attention to these items.

Storage Requirements for Dissolved Oxygen Control

Based on the projected waste loads presented in Table No. VIII-1, adequate treatment and the information on plant operation, waste release schedule and oxygen sag factors given in Exhibit No. 9, minimum streamflow requirements were computed to maintain the DO quality goal downstream from the 62 trading centers listed. Considering the need for water and the cost of providing this water for quality control, a protection throughout an average of 9 years out of ten is recommended. Water storage needs based on the uncontrolled flow below the existing Federal reservoirs are found at Grafton, Ada, Barnesville, Detroit Lakes, and Wahpeton-Breckenridge in the Red River of the North Basin. With releases from allocated storage in the existing reservoirs the water quality control needs at Wahpeton-Breckenridge can be met or exceeded at the 90 percent protection level and about 10 percent of the reservoir releases needed at Grafton for quality control can be met. Minor storage needs found downstream from 10 other trading centers on tributaries to the Red River are omitted since annual drafts-on-storage to maintain the DO quality objectives in 2015 are insignificant. Rather than list all the river basins and trading centers again, the annual drafts on additional storage to maintain the DO quality objective in the basin are listed in Table No. VIII-2.

Table No. VIII-2

Regulation Requirements to Meet

Dissolved Oxygen Objectives
(Draft-on-Storage in Acre-Feet per Year)

Red River of the North Basin Study

Year	Protection Level	Trading Centers Grafton	Ada	Barnesville	Detroit Lakes
2015	90	1460	180	770	670
	70	375	160	0	0
	50	228	140	0	0
1965	90	690	100	0	250
	70	120	80	0	0
	50	0	60	0	0

In critical years, drafts-on-storage for dissolved oxygen control may be required in the spring and fall at Ada, Barnesville, Detroit Lakes and Grafton. The year of first need at Barnesville will be about 1980. The other trading centers in Table No. VIII-2 presently need regulation for quality control during critical years.

IX. BENEFITS

Municipal and Industrial Water Supply

Improvements in quantity, dependability, quality and physical convenience of water use are considered primary municipal and industrial water supply benefits. "The amount water users should be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project." 94/

In the Pembina and Tongue Rivers Basin, the maximum monthly unsatisfied portion of the 2015 municipal and industrial water requirements are 0.10, 0.14, and 0.14 mgd at Neche, Pembina and Cavalier, respectively. Alternative sources of supply are sized to deliver these flows. On and off stream storage at each trading center and a well field with pipeline transmission costs are estimated as alternatives to storage at the reservoir site under consideration.

The three trading centers are located in the flat bottom land of the former glacial Lake Agassiz. Though small channel reservoirs are used by the municipalities, the terrain severely limits larger on stream storage. A sealed holding pond diked on 4 sides allowing for 2 feet of ice cover, 3 feet of freeboard and 2 feet of evaporation and seepage loss is used to estimate the cost of off stream storage.

Surface expressions show general availability of beach ridges in the valley. In discussions with the Geological Survey, it was determined that Cavalier, Pembina and Neche could develop ground water from beach ridges or buried deposits in the basin. However, additional test borings would be required to determine location and quality of water in these aquifers.

Pembina is located at the confluence of the Pembina and Red Rivers, and could obtain water from either river. An extension of the present intake system might be necessary to use Red River water, unless backwater from the Red River will inundate the present inlet during periods of low flow in the Pembina River. A small extension, less than ¼ of a mile, of the present intake could assure the ability to withdraw water from the Red River. The cost, if any, of Pembina obtaining water from the Red River would be small and is considered insignificant.

The value of storage for both Neche and Cavalier is considered equal to the cost of developing an alternate ground water source. The cost of test drilling and construction of a well field with up to 6-16" diameter wells and a transmission line up to 15 miles in length with a pumping station is estimated at $520,000. Pump and pipeline maintenance is estimated at $500 per year. The average annual operation and maintenance cost from the well field to Neche is estimated at $1250. Cavalier is not located adjacent to the Pembina River, and a transmission line from the river to the trading center will be required to use the Pembina River. The distance from the proposed Pembilier damsite to Cavalier is about 15 miles. The value of storage in this reservoir to meet 2015 municipal and industrial water requirements at Cavalier is considered the cost of developing an alternate ground water source and its transmission minus the cost of transmission from the reservoir. The value of storage estimated in this manner is $18,000.

In the Park River Basin, transmission of water from the Red River and on and off stream storage costs are estimated as alternatives to the projects under consideration. Ground water development is not considered because of the large transmission costs from the nearest large aquifer.

The cost of a single purpose on stream reservoir is based on operation and cost experiences with Homme reservoir. Operation of Homme has shown large transmission losses due largely to the gravel deposits in the stream bed between Park River and Grafton. During the summer months it requires an average reservoir discharge of about 20 cfs for 2 weeks in order to fill the 165 acre-foot channel reservoir at Grafton. 97/ During the winter months, a reservoir discharge of 18 cfs for 20 days is required to fill this channel reservoir. 97/ Off stream storage cost is computed in the previously mentioned holding pond design. Grafton has filed a water right application in the office of State Water Conservation Commission on the Red River in the amount of 7,000 acre-feet. The maximum monthly unsatisfied portion of the 2015 municipal and industrial water requirement is 0.6 mgd at Grafton. The lower mineral concentration of the Red River water and the smaller annual cost favor a 12 mile pipeline and pump stations capable of delivering 0.6 mgd from the Red River as the most likely alternative. The capital cost is estimated at $304,000. The operation and maintenance costs minus the power cost are estimated at $1,200 annually and the average annual power cost are estimated at $500.

In the Two River Basin, flow supplement needed to meet the 2015 municipal and industrial requirements at Hallock will be 0.16 mgd during the maximum month. The alternatives to reservoir storage investigated are off stream storage and a well and transmission line sized to deliver 0.16 mgd. Discussions with the Geological Survey revealed that good ground water aquifers are located within 12 to 15 miles of Hallock. Cost estimates show a well and the necessary transmission line and pumping stations to be the least costly. Based on other municipal well construction in the vicinity, a single well 8 inches in diameter and 200 feet in depth is used in the cost estimates. Total investment costs of $35,000 and an annual operation and maintenance cost of $600 plus an average annual power cost of $250 are estimated as necessary to develop a ground water source of supply. Lake Branson, owned by the State of Minnesota and operated to provide municipal water supply, has an available storage volume of 3606 acre-feet, that far exceeds the 2015 requirements at Hallock. There is no formal commitment between the State and Hallock relating to the release of water for use at Hallock. "It has always been done, however, and the practice will undoubtedly be continued." 93/ Under this condition, investment of funds by Hallock for water storage cannot be expected.

In the Tamarac River Basin, the Soil Conservation Service is preparing plans for two reservoirs for watershed protection. Storage for municipal water supply at Stephen was dropped from the project when Stephen municipal officials decided to develop the known ground water aquifer southeast of the City and use the Tamarac River as a supplementary source of supply. Investment in surface water treatment facilities presently needed have influenced this decision.

The maximum monthly flow supplement at Stephen expected by 2015 is 0.12 mgd above the natural streamflow. The capital cost of constructing a well, 4½ miles of pipeline and pumps capable of delivering 0.12 mgd to Stephen is estimated at $10,000. The annual operation and maintenance cost including an average annual power cost of $60 is estimated at $300.

The value of storing water for municipal and industrial purposes are listed in Table IX-1. This table presents the annual value of storage at the reservoir for a yield (given in Section VII) delivered to the trading centers in both thousands of dollars and dollars per thousand gallons.

Water Quality Control

"The net contribution to public health, safety, economy, and effectiveness in use and enjoyment of water for all purposes which are subject to detriment or betterment by virtue of change in water quality is considered the benefit from water quality control. The net contribution may be evaluated in terms of avoidance of adverse effects which would accrue in the absence of water quality control, including such damages and restrictions as preclusion of economic activities, corrosion of fixed and floating plant, loss or downgrading of recreational opportunities, increased municipal and industrial water treatment costs, loss of industrial and agricultural production, impairment of health and welfare, damage to fish and wildlife, siltation, salinity intrusion, and degradation of the aesthetics of enjoyment of unpolluted surface waters, or, conversely, in terms of the advantageous effects of water quality control with respect to such items. Effects such as these may be composited roughly into tangible and intangible categories, and used to evaluate water quality control activities. In situations where no adequate means can

Table No. IX-1

Value of M&I Water Supply Benefits

Red River of the North Basin

Value of Storage at	To	Cost ($1000)		First Need (Year)	1965 Annual Value*	
		Capital	O&M		($1000)	($/1000 Gal.)
Pembilier Reservoir	Pembina	None	None	1980	None	None
	Neche	520	1.25	1980	12.590	1.66
	Cavalier	18	None	1980	.4	0.02
Reservoir Upstream Grafton	Grafton	304	1.7	1990	5.9	0.04
Reservoir Upstream Hallock	Hallock	35	.85	1965	2.1	0.14
Reservoir Upstream Stephen	Stephen	10	.30	1965	.7	0.05

*Capital, operating and maintenance costs amortized at 4 percent for 25 years; present worth of 1 per period for 25 years at 3 1/8 percent, then amortized at 3 1/8 percent for 100 years to get annual value.

be devised to evaluate directly the economic effects of water quality improvement, the cost of achieving the same results by the most likely alternative may be used as an approximation of value." 94/

Beneficial Uses

Flow regulation from the recommended storage in the five tributary stream reaches will maintain the dissolved oxygen concentration at not less than 4.0 mg/l for 9 out of 10 years on the average. In maintaining water quality of streams to protect aquatic life, mere survival is not enough. The minimum level selected should be suitable for the continuous maintenance of satisfactory fish life and fish food organisms. As dissolved oxygen concentration declines from saturation, the quality of the aquatic environment and desired suitability for continuing growth of all parts of the aquatic life cycle grows less. While there is no sudden and spectacular die-off when the dissolved oxygen concentration falls to 4 mg/l, this value is generally accepted as representing a borderline condition. With more dissolved oxygen, conditions improve markedly and, with less, undesirable results become more apparent, culminating with widespread fish kills when the dissolved oxygen concentration drops below 2 mg/l. Zero DO concentrations not only result in loss of fish life but also create nuisance conditions seriously damaging the aesthetic and recreational value of the stream and adjacent property. Thus, maintenance of the DO quality criteria will reduce damage to the aquatic life in the stream and improve the recreational and aesthetic values stemming from clean surface waters and the absence of odors. Maintenance of sufficient flow to meet dissolved oxygen objectives is expected to aid in maintaining levels of sulphate, chloride, sodium and other chemical quality parameters below objectionable concentrations.

In general, assured water quality will provide favorable conditions for recreation such as swimming, water skiing, boating and fishing. However, the physical features of most streams in the study area preclude some recreational uses.

The watercourse from the Detroit Lakes waste treatment plant flows through a series of highly developed recreational lakes, of which the first, Lake Sally, is four to five miles downstream. These lakes are used for boating, water skiing, swimming and fishing. One of the main sources of income for the City is derived from tourists and summer residents many of whom live in cottages on lakes downstream from the waste treatment plant. In the past before additional waste treatment facilities were constructed, these summer residents have complained to the City about nuisance conditions developing in Lake Sally which they believed were caused by effluent from the waste treatment plant.

The limited water surface and depth is expected to severely limit recreational uses in the three other reaches. For example, 96/ the Park River is known to support a small sport fishery for bullhead, perch, sucker, and pike. Most of the fishing is done during the period of spring high water when fish are moving upstream from the Red River. Pike and suckers constitute the bulk of the catch during this period. During the rest of the year, the small size of the stream limits its carrying capacity, and most of the fishing is done by children seeking perch and bullheads in the pools.

The present fishing pressure on the Red River of the North and its major tributaries (excluding the upper reach of Red Lake River and portions of the Sheyenne River) is very low. This is largely due to the poor quality fishery prevailing in these streams. In addition, the esthetics of most of these streams is such that they generally are not attractive and they fail to compete effectively with the lakes and streams of north-central Minnesota. 98/

In 1963 the commercial catch in the Basin (excluding the Red Lakes) amounted to approximately 1,804,000 pounds valued at $89,300. According to information received from the States of Minnesota and North Dakota, commercial fishing in the Basin is primarily limited to the lakes and reservoirs---The Pelican River from its confluence with the St. Clair ditch to Lake Sally, Lake St. Clair, Lake Sally and Muskrat Lake. Our records show approximately 2,450 pounds of fish are removed from Muskrat Lake in 1963 and 5,900 pounds from Lake Sally the same year. Value of the catch from Lake Sally was $295 and $64 from Muskrat Lake, the latter figure including only the State of Minnesota's share of the receipts. No commercial fishing was reported on the other stream reaches of concern. 99/ Based on the limited information available, prospects for development of a significant commercial fishery at least in the near future, do not appear bright regardless of water quality improvement. 99/

Protection of mineral quality will benefit municipal and industrial users and irrigators in the study area and downstream in Canada. These benefits are reflected in improved palatability, decreased plumbing costs, reduced treatment costs and greater uniformity of composition throughout the year. The latter two factors will be a strong attraction to water using industries. For the irrigator, maintenance of low dissolved solids results in lower application rates, reduced pumping costs and lower field costs. Without regulation, stream quality would be poorest during the irrigation season.

Other benefits derived from maintaining water quality will be a reduction in the public health hazard in the downstream municipal water supply, and a reduction of the health danger to livestock watering downstream.

From the above, it is concluded that benefits are widespread in scope and warrant the provision of storage for the required streamflow regulation. Total benefits from regulation of streamflow for water quality control purposes will accrue only if adequate treatment is provided.

If required storage for streamflow regulation is not provided as recommended, water treatment costs at downstream usage points may be expected to increase, damage to paint on structures adjacent to or in the stream reaches may be anticipated, and property values will decline in areas contiguous to these reaches. Lacking a water supply of assured quality as well as quantity, industry will be less likely to select plant sites along these stream reaches, all other things being equal, which means economic growth in portions of the study area will be restricted. Recreation will suffer. Without streamflow regulation, it is estimated that the projected waste loads will result in a dissolved oxygen concentration in the four reaches that may cause fish to leave the area in favor of waters that provide the environment they require. As waste loads continue to increase, conditions in the receiving streams will continue to worsen. Unless there is streamflow regulation, unsatisfactory conditions may occur in these reaches of stream.

Without flow regulation, irrigation and restoration of Devils Lake will impose serious mineral quality problems on water users on the main stem in the United States and Canada.

Value of Benefits

The value of the benefits of storage for water quality control is approximated by calculating the cost of the most likely alternative. Alternatives considered in estimating values include: single purpose reservoirs; storage of water in off stream sites at the point of need; holding ponds for storage of treated wastes; transmission of treated waste via pipeline to streams which can assimilate the effluent; inter-basin transfer of water; and use of developed ground water source.

In the Park River the alternative means of maintaining water quality on which cost estimates are made are a single purpose reservoir. Off stream storage of water near Grafton, holding a portion of the treated wastes at Grafton, during periods of low flow, and pipeline transmission of a portion of the treated wastes to the Red River. Cost of a single purpose reservoir is based on experience with transmission losses and costs at Homme. Pipeline transmission costs are based on use during the spring and fall.

The volume of waste effluent that must be held is considerably smaller than the volume of water need for quality control. The most likely alternative is 120 acre multi-cell holding pond diked on four sides with a capital cost of $250,000 an annual operating and maintenance cost of $3,000.

In the Marsh River Basin, the water quality control needs can be met by pumping the developed ground water source, by diversion of water from the Wild Rice River, by off stream storage of water, and by retaining a portion of the waste effluent. The Marsh and Wild Rice

Rivers have been connected above Ada approximately 51 miles upstream from the mouth of the Wild Rice. The interbasin diversion of water from the Wild Rice to the Marsh is controlled at a weir. The weir crest is at elevation 919.0 feet which is about 0.5 feet below the normal water surface and about 2.5 feet above the thalweg of the stream. [95/] The flow in the Wild Rice River exceeds that needed for quality control purposes at Ada. This alternative requires no construction costs, and the minor operation and maintenance costs are considered insignificant.

In the Buffalo River Basin, the water quality needs can be met by storage of water and by retaining a portion of the waste effluent in a holding pond. The volume of waste discharges that must be stored is considerably smaller than the volume needed for quality control in a storage reservoir. The water quality control needs are in Willow Creek below Barnesville, because of the small drainage area upstream, reservoir storage is limited. The most likely alternative is a 90 acre holding pond diked on four sides with a capital cost of $205,000 and an annual operation and maintenance cost of $2,500.

In the Otter Tail River Basin the need for water quality control storage is at Detroit Lakes in the headwaters of the Pelican River. When evaporation losses are considered, the off stream storage volume needed to hold a portion of the waste effluent is smaller than that needed for quality control water. The capital cost of the most likely alternative, a 170 acre multi-cell holding pond diked on four sides with one interior dike, is estimated at $360,000 with an annual operation and maintenance cost of $4,500. However, in 1964 the City of Detroit Lakes enlarged its secondary treatment plant and,added in series, an aerated lagoon and a stabilization pond at a capital cost of $100,000. Analyses of the plant effluent gave BOD concentrations which would not require dilution during recommended release periods. Based on the additional treatment the year of first need for flow regulation for quality control is expected in 1985, the end of the design period for the plant.

The value of benefits for the provision of storage for mineral quality control was based on the cost of the most likely alternatives, in this case, single purpose reservoirs to supply annual drafts on storage of 60,000 and 80,000 acre-feet each. The capital cost of each reservoir was based on cost figures in Committee Print 32, U. S. Senate Select Committee on National Water Resources. The capital costs so derived were amortized over the 100 year project life at the Federal interest rate of 3.125%. Annual value of benefits, including operation and maintenance costs are $145,000 and $165,000 respectively.

The dollar value of benefits attributable to water are summarized in Table IX-2. Annual values are developed by amortizing over a 100 year period discounting from the time of first need at 3-1/8 percent rate of interest. The values given are for storage necessary to deliver the net regulation requirements (see Table No. VIII-~~3~~2) to the points of need via on stream transmission.

Table No. IX-2

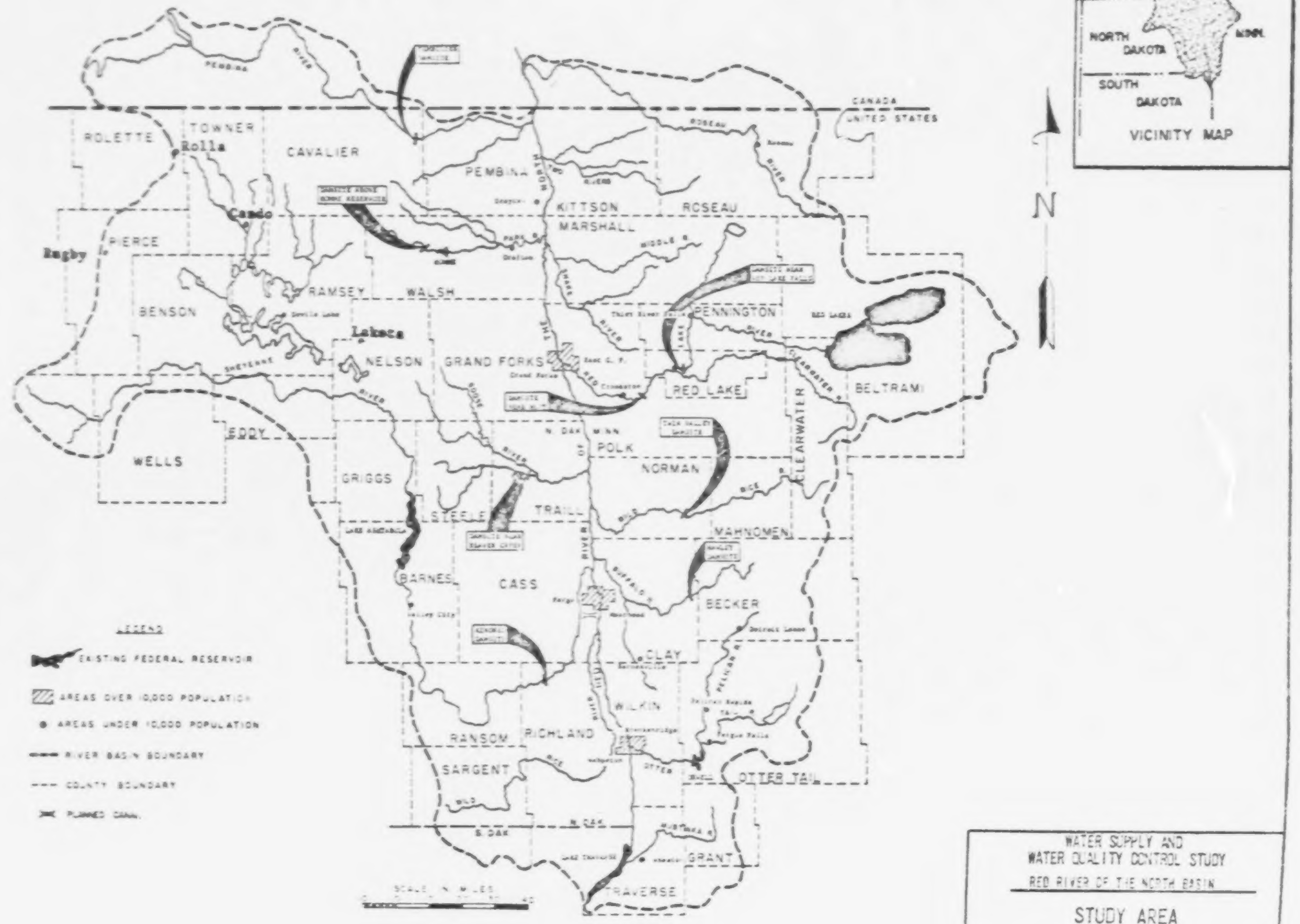
Value of Water Quality Control Benefits

Red River of the North Basin

Value of Storage at	Costs in $1000 Capital	Costs in $1000 O&M	Year of First Need	1965 Annual Value
Reservoir Upstream Grafton	220	3.0	1965	$ 10,000
Reservoir Upstream Ada	---	---	1965	None
Reservoir Upstream Barnesville	205	2.5	1978	6,000
Reservoir Upstream Detroit Lakes	360	4.5	1985	9,000
Reservoirs on Eastern Tributaries above Fargo	4,230	28	1/	165,000
Kindred Dam	3,600	28	2/	145,000

1/Activation of Oaks unit

2/Operation of Warwick-McVille and New Rockford units


CANADA
NORTH DAKOTA
MINN.
SOUTH DAKOTA
VICINITY MAP
N
CANADA
UNITED STATES
PEMBINA RIVER
ROSEAU RIVER
ROLETTE
Rolla
TOWNER
CAVALIER
PEMBINA
KITTSON
ROSEAU
Cando
Rugby
PIERCE
MARSHALL
RAMSEY
WALSH
BENSON
Devils Lake
Lakota
NELSON
GRAND FORKS
PENNINGTON
RED LAKES
BELTRAMI
RED LAKE
CLEARWATER
SHEYENNE RIVER
WELLS
EDDY
GRIGGS
POLK
NORMAN
STEELE
TRAILL
MAHNOMEN
LAKE ASHTABULA
BARNES
CASS
BECKER
CLAY
WILKIN
RANSOM
RICHLAND
SARGENT
OTTER TAIL
GRANT
TRAVERSE
N. DAK
S. DAK
MINN
LEGEND
EXISTING FEDERAL RESERVOIR
AREAS OVER 10,000 POPULATION
AREAS UNDER 10,000 POPULATION
RIVER BASIN BOUNDARY
COUNTY BOUNDARY
PLANNED CANAL
SCALE IN MILES

WATER SUPPLY AND
WATER QUALITY CONTROL STUDY
RED RIVER OF THE NORTH BASIN

STUDY AREA

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MISSOURI

X. BIBLIOGRAPHY

1. Minnesota State Board of Health, *Pollution of the Red River of the North*, A report of joint investigation by the Minnesota State Board of Health and the North Dakota State Board of Health, in collaboration with the Division of Game and Fish, Minnesota Department of Conservation, 1931, 1932, 1933.

2. North Dakota State Department of Health, *Red River of the North Research Investigation*, A report covering the joint investigation by the North Dakota State Department of Health, The Minnesota State Board of Health in collaboration with the United States Public Health Service (1938-1941).

3. Public Health Service, "A Preliminary Report - Water Needs in the Red River of the North for Domestic and Sanitary Purposes," Missouri River Basin Office, Kansas City, Missouri, June 1949.

4. Corps of Engineers, "Water Use Survey, International Souris-Red Rivers Engineering Committee, Red River Watershed," St. Paul District Office, January 1950.

5. Public Health Service, *A Comprehensive Program for Water Pollution Control for the Red River of the North Basin*, Government Printing Office, Washington, 1953. (Water Pollution Series, No. 53.)

6. Public Health Service, *Missouri-Souris Development Area, Water Pollution Investigation*, A cooperative State-Federal report on water pollution, November 1951. (Water Pollution Series, No. 32.)

7. Public Health Service, "Re-evaluation of the Missouri-Souris Development Area Water Pollution Investigations." Region VI, Kansas City, Missouri, April 1956.

8. House Document No. 185, 81st Congress, 1st Session, *Red River of the North Drainage Basin, Minnesota, South Dakota, and North Dakota*, 24 May 1948.

9. Corps of Engineers, "Report on Water Supply and Water Conservation Needs in the Red River of the North Drainage Basin, Minnesota, South Dakota, and North Dakota," St. Paul District Office, 21 August 1961.

10. Corps of Engineers, *River Basin Plan, Souris-Red Rivers Basin*, St. Paul District Office, September 1961.

11. Geological Survey, *Surface Water Records of North Dakota and South Dakota - 1962 and 1961*, Water Resources Division, Bismarck, North Dakota.

12. Geological Survey, *Surface Water Supply of the United States*, Part 6-A, "Missouri River Basin Above Sioux City, Iowa," 1950 through 1960, Government Printing Office, Washington, 1961.

13. Geological Survey, Surface Water Records of Minnesota - 1961 and 1962, Water Resources Division, St. Paul, Minnesota.

14. Public Health Service, Municipal Water Facilities Inventory as of January 1, 1958, "Region VI," A Cooperative State-Federal Report, Government Printing Office, 1960.

15. Public Health Service, Municipal Water Facilities Inventory as of January 1, 1963, "Region VI," A Cooperative State-Federal Report, Government Printing Office, 1964.

16. Public Health Service, Region VI, Construction Grants files of Preliminary Engineering Reports.

17. Minnesota State Department of Health, letter dated March 2[illegible] 1964.

18. Public Health Service, Region VI, Water Resources files, reports on field investigations at St. Paul, Bismarck, etc., dated March 1964 and November 1964.

19. Public Health Service, 1962 Inventory - Municipal Waste Facilities, "Region VI," A Cooperative State-Federal Report, Government Printing Office, 1963. (PHS Publication No. 1065, volume 6.)

20. Minnesota State Department of Health, Summary of Census Data on Sewage Disposal Facilities in Minnesota, Minneapolis, Minnesota, January 1963.

21. Public Health Service, Water Resources Study, Pembina River Basin, North Dakota, Region VI Kansas City, Missouri, May 1963.

22. Public Health Service, National Water Quality Network, Annual Compilation of Data, October 1, 1959 - September 30, 1962, Public Health Service Publication No. 663. (1960, 1961, 1962 editions.)

23. Marion L. Maderak, Minnesota Conservation Department, Quality of Water, Minnesota, A Compilation, 1955-62, St. Paul, Minnesota, June 1963. (Bulletin 21)

24. Minnesota State Department of Health, "Minnesota Municipal Water Supply Chemical Quality Records," Unpublished Records, 1948-1962.

25. Geological Survey, Chemical Analyses of Surface Waters, North Dakota, October 1959 to September 1962, and Sheet No. 5-996, "Pembina River at Walhalla, North Dakota," for water year October 1962 to September 1963, Unpublished Records, Lincoln, Nebraska.

26. Geological Survey, Quality of Surface Waters of the United States, 1954-1959, Parts 5-6, "Hudson Bay and Upper Mississippi River Basins, and Missouri River Basin," Government Printing Office, Washington: 1958 to 1962.

27. Minnesota Water Pollution Control Commission, *Water Quality Sampling Program, Minnesota Lakes and Streams, A Compilation of Sampling Station Records,* vol. 1, 1953-1957, and vol. 3, 1960-1961, Minnesota Department of Health, Minneapolis, Minnesota, March 1961 and October 1963.

28. Corps of Engineers, *Reservoir Regulation Manual*, "Flood Control and Water Conservation, Otter Tail River, Minnesota, Red River of the North Watershed, Orwell Dam and Reservoir," U. S. Army Engineer District, St. Paul, Minnesota, April 1954 (revised September 1963).

29. Corps of Engineers, *Reservoir Regulation Manual*, "Flood Control, Sheyenne River, North Dakota, Baldhill Dam and Lake Ashtabula," U. S. Army Engineers District, St. Paul, Minnesota, October 1952 (revised March 1956).

30. Corps of Engineers, *Reservoir Regulation Manual*, "Flood Control, South Branch Park River, North Dakota, Homme Dam and Reservoir," U. S. Army Engineer District, St. Paul, Minnesota, December 1955.

30a. Corps of Engineers, Telephone Conversation Record of October 2, 1964, U. S. Army Engineers District, St. Paul, Minnesota.

31. Bureau of Census, *U. S. Census of Population: 1940-1960*, Volume II, "Characteristics of the Population," U. S. Government Printing Office, Washington: 1942-1962.

32. Bureau of Census, *U. S. Census of Agriculture: 1949-1959*, Volume I, Government Printing Office, Washington: 1950-1961.

33. Department of Agricultural Economics, *North Dakota Price Trends, 1950-63*, North Dakota Crop & Livestock Reporting Service, Comp., Fargo, North Dakota, January 1964. (Ag. Statistics No. 11.)

34 Learn, Elmer W., Cox, Rex W., and Herder, Richard J., *Upper Midwest Agriculture: Alternatives for the Future*, Upper Midwest Economic Study, University of Minnesota, Minneapolis, Minnesota, December 1962. (Study Paper No. 6.)

35. Department of Agricultural Economics, *North Dakota Crop & Livestock Statistics, 1962*, North Dakota Crop & Livestock Reporting Service, Comp., Fargo, North Dakota, May 1963. (Agricultural Statistics No. 10.)

36. "Sugar: A New Era Begins," *Monthly Review*, Federal Reserve Bank of Kansas City, Kansas City, Missouri, March-April 1964.

37. "Potatoes From the Valley," *Monthly Review*, Federal Reserve Bank of Minneapolis, Minneapolis, Minnesota, July 1963.

38. Department of Agriculture, *Agricultural Statistics, 1960*, Government Printing Office, Washington: 1961.

39. Bureau of Mines, *Minerals Yearbook: 1953-1961*, Volume III "Area Reports," Government Printing Office, Washington: 1954-1962.

40. North Dakota Economic Development Commission, *A Comprehensive Look At North Dakota*, Bismarck, North Dakota, 1963.

41. Bureau of Census, *U. S. Census of Manufacturers: 1948-1958*, Volume III, "Area Statistics," Government Printing Office, Washington: 1951-1961.

42. Bureau of Census, *U. S. Census of Population: 1930-1960*, Volume I, "Number of Inhabitants," Government Printing Office, Washington: 1931-1961.

43. Nason, Law, Wehrman & Knight, Inc., Community Planning Consultants, *Grand Forks Master Plan*, Minneapolis, Minnesota, May 1961 to November 1962.

44. Bureau of Reclamation, *Report on Garrison Diversion Unit, Garrison Division, North Dakota and South Dakota*, Missouri-Souris Projects Office, Bismarck, North Dakota, January 1957.

45. Bureau of Reclamation, *Supplemental Report on Garrison Diversion Unit (Initial Stage - 250,000 Acres), Garrison Division, North Dakota - South Dakota*, Missouri-Souris Projects Office, Bismarck, North Dakota, November 1962, revised May 1963.

46. Barton-Aschman Associates, Inc., *Prospectus for Comprehensive Planning and Transportation Studies, Fargo, Southwest Fargo-Moorhead, Dilworth Metropolitan Area*, Evanston, Illinois, September 1963.

47. Johnson, Jerome E., and Goodman, Richard J., *Negative Impacts of Garrison and Oahe Reservoirs on the North Dakota Economy*, North Dakota State University of Agriculture and Applied Science, Fargo, North Dakota, April 1962. (Agricultural Economics Report.)

48. *New Dimensions for Minnesota*, Department of Administration, Documents Section, St. Paul, Minnesota, January 1963.

49. Voelker, Stanley W., *Economic and Sociological Trends Affecting Town and Country Churches in North Dakota*, North Dakota Council of Churches, Fargo, North Dakota, September 1962.

50. North Dakota Economic Development Commission, *North Dakota Growth Indicators*, Bismarck, North Dakota, September 1961.

51. Trock, Warren L., Cattle Feeding in the Northern Great Plains, University of Minnesota, Minneapolis, Minnesota, January 1963. (Technical Paper No. 5.)

52. Knudtson, Arvid C., Cox, Rex W., and others, Upper Midwest Agriculture: Structure and Problems, University of Minnesota, Minneapolis, Minnesota, April 1962. (Technical Paper No. 2.)

53. Knudtson, Arvid C., Cox, Rex W., and others, Upper Midwest Agriculture: Structure and Problems, University of Minnesota, Minneapolis, Minnesota, January 1962. (Study Paper No. 3.)

54. Department of Labor, Projections to the Years 1976 and 2000: Economic Growth, Population, Labor Force, and Leisure, and Transportation, Government Printing Office, Washington: 1962. (ORRRC Study Report 23.)

55. North Dakota Agricultural Experiment Station, A Summary Statement: Some Economic Considerations in the Garrison Diversion Irrigation Project, North Dakota State University, Fargo, North Dakota, October 1963.

56. Valley Potato Grower 62-63 Annual Report, Red River Valley Potato Growers Association, East Grand Forks, Minnesota, vol. XVII, No. 13, July 15, 1963.

57. Larson, Arlyn J., and Koenker, William E., Estimated Indirect Benefits from Irrigation in North Dakota, University of North Dakota, Grand Forks, North Dakota, February 1961. (North Dakota Economic Studies No. 6.)

58. Kelley, Jr., Samuel C., and Associates, Irrigation in North Dakota: The Potential Economic Impact of the Program Proposed by the Bureau of Reclamation, University of North Dakota, Grand Forks, North Dakota, August 1954. (North Dakota Economic Studies No. 2.)

59. Kelley, Jr., Samuel C., and Associates, The Population, Labor Force, and Income of North Dakota, 1900-1975, University of North Dakota, Grand Forks, North Dakota, April 1954. (North Dakota Economic Studies No. 1.)

60. Hertsgaard, Thor A., Taylor, Fred R., Tetrault, Alvah R., The North Dakota Economy, Bulletin No. 428, "Factors Related to Economic Development," North Dakota Agricultural Experiment Station, Fargo, North Dakota, October 1960.

61. Letter to Public Health Service, Regional Office, Kansas City, Missouri, dated November 19, 1964, from Bureau of Reclamation, Missouri-Souris Project Office, Bismarck, North Dakota.

62. U. S. Congress, Senate, Select Committee on National Water Resources, Water Resources Activities in the United States, "Population Projections and Economic Assumptions," Government Printing Office, Washington: 1960. (82nd Congress, 2d Session, Committee Print No. 5.)

63. Public Health Service, Public Health Service Drinking Water Standards, 1962, Government Printing Office, Washington: 1962.

64. U. S. Congress, Senate, Select Committee on National Water Resources, Water Resources Activities in the United States, "Future Water Requirements for Municipal Use," Government Printing Office, Washington: 1960. (82d Congress, 2d Session, Committee Print No. 7.)

65. Public Health Service, Waste Treatment Studies, by Ralph Porges, Technical Report W62-3, "Wastes from the Poultry Processing Industry," Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, 1962.

66. Public Health Service, An Industrial Waste Guide to the Meat Industry, Government Printing Office, Washington: 1954. Public Health Service Publication No. 386.

67. Public Health Service, An Industrial Waste Guide to the Milk Processing Industry, Government Printing Office, Washington: Revised 1959. Public Health Service Publication No. 298.

68. Bolton, J. M., "Wastes from Poultry Processing Plants," Paper presented at the Proceedings of the Thirteenth Industrial Waste Conference, May 1958, Purdue University, Lafayette, Indiana.

69. Straub, Conrad P., "Statistical Evaluation of Packing House Waste Data," Paper presented at the Proceedings of the Eighth Industrial Waste Conference, May 1953, Purdue University, Lafayette, Indiana.

70. Francis, Robert L., Characteristics of Potato Flake Processing Wastes, Journal Water Pollution Control Federation, March 1962, Washington, D. C.

71. Cooley, A. M., and others, "Characteristics and Amounts of Potato Wastes from Various Process Streams," a paper presented at the 19th Annual Industrial Waste Conference, May 5-7, 1964, Lafayette, Indiana.

72. Minnesota State Department of Health, "Summary Report on Status of Waste Disposal at Potato Processing Plants in Minnesota," Unpublished data, March 1964.

73. Minnesota State Department of Health, "Summary Report of Spray Irrigation Facilities at the Fosston Potato Products Company," Unpublished data, March 1962.

74. Memorandum on Status of Sugar Beet Refinery Waste Disposal, Minnesota State Department of Health, August 1, 1963.

75. Unpublished report from the American Crystal Sugar Company to the Minnesota State Department of Health, "Waste Water Disposal at the Moorhead Factory of the American Crystal Sugar Company," May 1963.

76. Geological Survey, *Ground Water in the Vicinity of Hillsboro, Traill County, North Dakota*, by H. M. Jensen and Edward Bradley, North Dakota State Water Conservation Commission, Bismarck, North Dakota, 1963. (North Dakota Ground-Water Studies No. 55.)

77. U. S. Geological Survey, *Ground-Water Sources in the Vicinity of Northwood, Grand Forks County, North Dakota*, by H. M. Jensen, North Dakota State Water Conservation Commission, Bismarck, North Dakota, 1961. (North Dakota Ground-Water Studies No. 34.)

78. U. S. Geological Survey, *Ground Water in the Portland Area, Traill County, North Dakota*, by P. E. Dennis and P. D. Akin, A Cooperative Federal-State Report, Government Printing Service, Washington: 1950. (North Dakota Ground Water Studies No. 15.)

79. North Dakota State Department of Health, *Chemical Analyses of Municipal Waters in North Dakota*, Bismarck, North Dakota, 1954 and 1964.

80. U. S. Congress, House, *Garrison Diversion Unit, North Dakota and South Dakota, Missouri River Basin Project*, 86th Congress, 2d Session, H. R. 325, Government Printing Office, Washington: 1960.

81. **Adolphson, D. G., *Test Drilling in the Walhalla Area, Pembina County, North Dakota,* Open File Report, U. S. Geological Survey, October, 1960.**

82. Letters to Corps of Engineers, St. Paul, Minnesota, dated June 7, 1962, and August 24, 1964, and to Geological Survey, St. Paul, Minnesota, dated March 25, 1964, from Bureau of Reclamation, Missouri-Souris Projects Office, Bismarck, North Dakota.

83. Letter to Corps of Engineers, St. Paul, Minnesota, dated September 12, 1962, from Bureau of Reclamation, Billings, Montana.

84. State-Federal Crop and Livestock Reporting Service, *Minnesota Agricultural Statistics*, St. Paul, Minnesota, 1958-1963.

85. Geological Survey, *Chemical Quality of Surface Waters in Devils Lake Basin, North Dakota*, by H. A. Swenson and B. R. Colby, Government Printing Office, Washington: 1955. (Water Supply Paper 1295).

86. Bureau of Reclamation, Region VI, Definite Plan Report on Garrison Diversion Unit, Missouri River Basin Project, Appendix B -- Water Supply, Book 2 -- Operation Computations, Missouri-Souris Project Office, Bismarck, North Dakota, September 1963.

87. Paulson, Q. F., Ground Water, A Vital North Dakota Resource, North Dakota Geological Survey, Grand Fork, North Dakota, 1962.

88. Public Health Service, "Future Water Supply and Quality Control Aspects of the Goose River, North Dakota," Region VI, Kansas City, Missouri, September 1962.

89. Paulson, Q. F., "Geological Factors Effecting Discharge of the Sheyenne River in Southeastern North Dakota," Geological Survey Professional Paper No. 501-D, unpublished.

90. Dennis, P. E., et al, "Geology and Ground Water Resources of Parts of Cass and Clay Counties North Dakota and Minnesota," North Dakota Ground Water Study No. 11, 1949.

91. Maclay, R. W., and Schiner, G. R., "Aquifers in Buried Shore and Glaciofluvial Deposits Along the Gladstone Beach of Glacial Lake Agassiz near Stephen, Minnesota," Geological Survey Research, 1962, Government Printing Office, Washington, D. C.

92. Brookhart, J. W. and Powell, J. E., "Reconnaissance of Geology and Ground Water of Selected Areas in North Dakota," North Dakota Ground Water Study No. 28, North Dakota State Water Conservation Commission, Bismarck, North Dakota, 1961.

93. Correspondence 12/9/64, State of Minnesota, Department of Conservation, Division of Waters.

94. U. S. Congress, Senate, Policies, Standards, and Procedures in the Formulation, Evaluation, and Review of Plans for Use and Development of Water and Related Land Resources, The President's Water Resources Council and Senator Clinton P. Anderson, (87th Congress,2d Session, Document No. 97) U. S. Government Printing Office, Washington: 1962.

95. Corps of Engineers, Flood Control Red River of the North Drainage Basin, Minnesota, South Dakota and North Dakota, Drawings, Nos. R-R-7/43 and R-R-7/44 U. S. Engineer District, St. Paul, Minnesota, September, 1947.

96. Fish & Wildlife Service, "A Report on Fish and Wildlife Resource in Relation to the Water Development Plan of the Park River Reservoir on the South Branch of the Park River", Washington, D.C., 1947

97. Letter from the Corps of Engineers, St. Paul, Minnesota, dated June 4, 1965

98. Letter from Bureau of Sport Fisheries and Wildlife, U.S. Department of the Interior, Minneapolis, Minnesota, dated April 5, 1965

99. Letter from Bureau of Commercial Fisheries, U.S. Department of the Interior, Ann Arbor, Michigan, dated April 29, 1965

Exhibit No. 1

Historical Streamflows

Red River of the North Basin Study

Station	Drainage Area Square Miles	Location	River Mile From Mouth	Years of Record	Flows in CFS Maximum	Minimum	Average
Red River of the North at Emerson, Manitoba	40,200	3/4 mile downstream from International Boundary	154	50	95,500	0.9	2,320
Pembina River at Neche, N. Dak.	3,360	Above confluence of Tongue River	24e	54	10,700	0	161
Tongue River at Akra, N. Dak.	162	Middle reach of river	36e	11	11,800	0	16
South Branch of Two Rivers at Lake Bronson, Minnesota	444	Above confluence of Middle & North Branches	20e	21	2,960	0	69
Roseau River at Ross, Minnesota	1,220	Downstream from Pine Creek	–	34	6,360	0	229
Red River of the North at Drayton, N. Dak.	34,800	Downstream from Park and Snake Rivers' confluence	207	13	86,500	7.7	3,267
Park River at Grafton, N. Dak.	695	Downstream from South Branch	30	31	12,600	0	50
Middle River at Argyle, Minn.	265	Upstream from confluence with Snake River	14	12	1,620	0	31
Forest River at Minto, N. Dak.	740	Below South & Middle Branches	21	18	16,600	0	46
Turtle River at Manvel, N. Dak.	613	Below North & South Branches	10	17	28,000	0	47
Red River of the North at Grand Forks, N. Dak.	30,100	2 miles downstream from Red Lake River	296	80	80,000	2.4*	2,306
Red Lake River at Crookston	5,280	Downstream from Black River	40e	61	27,400	0*	979
Goose River at Hillsboro, N. Dak.	1,220	Below North Branch confluence	22	29	9,420	0	46
Wild Rice River at Hendrum, Minn.	1,600	Downstream from South Branch	4	18	4,660	0	209
Wild Rice River at Twin Valley, Minnesota	888	Upstream from South Branch	70e	40	9,200	0.5	158
Buffalo River near Dilworth, Minn.	1,040	9 miles downstream from South Branch	9e	31	6,140	0	116
Buffalo River near Hawley, Minn.	322	Upstream from South Branch	40e	17	1,590	6.8	72
Sheyenne River at West Fargo, N. Dak.	8,870**	3 miles upstream from Maple River	26	35	2,810	2	168
Sheyenne River at Lisbon, N. Dak.	8,190**	Upstream from Timber Coulee	162	6	2,400*	3.6*	83
Maple River near Mapleton, N. Dak.	1,460	Upstream from confluence with Sheyenne River	14	18	4,840	0	50
Red River of the North at Fargo, N. Dak.	6,800	Upstream from mouth of Sheyenne River	453	61	9,580	0	504
Wild Rice River near Abercrombie, N. Dak.	2,080***	Below confluence at Antelope Creek	29e	30	5,500	0	65
Red River of the North at Wahpeton, N. Dak.	4,010	Downstream from Bois de Sioux & Otter Tail Rivers	549	19	7,130	8	516
Bois de Sioux River near White Rock, S. Dak.	1,160	300 ft. downstream from White Rock Dam	–	21	1,620*	0*	82
Otter Tail River near Fergus Falls, Minnesota	1,830	0.7 mile downstream from Orwell Dam	29e	32	1,710	1.6	254

e - estimated
* - Caused by regulation
** - About 5,800 non-contributing
*** - About 600 non-contributing

Source: Geological Survey 11, 12/

Exhibit No. 2

Municipal Water Supply

Red River of the North Basin Study

Subarea	State	County	Municipality	1963 Population Served	Source of Supply	Rated Plant Capacity MGD	Average Output MGD	GPCD
I	Minnesota	Kittson	Hallock	1,930	South Branch Two Rivers	0.216	-	-
			Karlstad	685	Well	.4	0.023	34
			Lake Bronson	400	Wells	.07	.03	73
			Kennedy	440	Well	.28	.035	80
		Roseau	Roseau	2,200	Wells	1.26	.181	85
			Badger	338	Well	0.11	-	-
			Greenbush	700	Well	.22	.02	29
		Marshall	Warren	2,007	Wells	.67	.152	76
			Alvarado	280	Wells	.140	.03	107
			Argyle	789	Well	.120	.065	82
			Middle River	400	Well	.14	.01	25
			Newfolden	355	Well	.14	.04	113
			Oslo	372	Red River of the North	.8	.060	161
			Stephen	820	Tamarac River	-	.060	73
			Strandquist	160	Well	.036	.018	112
	North Dakota	Cavalier	Langdon	2,000	Infiltration Gallery	-	.112	56
			Osnabrock	286	Wells	-	.020	71
		Pembina	Cavalier	1,600	Wells & Tongue River	.288	.120	86
			Drayton	950	Red River of the North	.175	.060	63
			Mountain	100	Well	-	-	-
			Neche	3,450	Pembina River	.430	.120	35
			Pembina	~~1,200~~ *	Pembina River	.190	.050	62
			Walhalla	1,450	Wells	-	.042	29
		Walsh	Adams	355	Well	-	.018	51
			Grafton	6,000	Park River	-	.500	83
			Minto	620	Wells	-	.060	65
			Park River	1,800	South Branch Park River & Wells	.400	.140	78
II	Minnesota	Beltrami	Blackduck	-	Wells	.375	.05	-
			Kelliher	290	Wells	.14	.04	138
		Clearwater	Bagley	-	Wells	.570	.080	-
			Gonvick	300	Well	.16	.008	27
			Clearbrook	-	Well	.18	.01	-
		Polk	Climax	-	Wells	.39	.02	-
			Crookston	9,500	Red Lake River	-	1.03	108
			E. Grand Forks	7,300	Red Lake River	2.300	0.84	115
			Erskine	590	Wells	0.39	.035	59
			Fertile	955	Wells	.70	.10	105
			Fisher	326	Well	.09	.02	61
			Fosston	1,704	Wells	.86	.10	59
			McIntosh	780	Wells	.32	.05	66
			Nielsville	183	Wells	.54	-	-
			Winger	292	Well	.18	.01	34
		Red Lake	Oklee	500	Well	.36	.025	50
			Plummer	200	Well	.18	.015	75
			Red Lake Falls	1,450	Wells	.23	.075	52
		Pennington	Goodridge	120	Well	.10	-	-
			St. Hilaire	270	Well	.21	-	-
			Thief River Falls	7,160	Red Lake River	1.2	.67	94
	North Dakota	Grand Forks	Grand Forks	48,140	Red River & Red Lake River	-	3.125	65
			Larimore	1,712	Wells	0.600	0.150	88
			Northwood	1,050	Wells	.100	.050	48
III	North Dakota	Traill	Hatton	950	Wells	-	.060	62
			Hillsboro	1,300	Wells	-	.100	77
			Mayville	2,200	Goose River & Wells	-	.140	64
			Portland	520	Well	-	.013	25
		Steele	Finley	800	Well	-	.050	62
			Hope	390	Well	-	.025	64
			Sharon	250	Wells	-	.015	60
IV	Minnesota	Norman	Ada	2,100	Wells	-	.150	71
			Halstad	600	Wells	.430	.040	67
			Hendrum	290	Well	.130	.025	86
			Perley	130	Wells	.200	.015	115
			Shelly	190	Wells	.200	.015	79
			Twin Valley	800	Wells	.300	.035	64
		Mahnomen	Bejou	160	Well	.03	.01	62
			Mahnomen	1,450	Wells	1.0	.03	21
V	Minnesota	Clay	Barnesville	1,550	Wells	0.580	.110	71
			Dilworth	2,050	Wells	.400	.100	69
			Hawley	1,120	Wells	.300	.075	67
			Hitterdale	100	Well	.100	.005	50
			Moorhead	23,000	Red River of the North & Wells	6.5	2.06	90
			Ulen	420	Wells	0.290	0.045	107
	North Dakota	Cass	Amenia	100	Wells	-	.005	50
			Arthur	300	Well	-	.015	50
			Casselton	1,450	Reservoir & Wells	-	.12	83
			Fargo	49,000	Red River of the North	14.3	6.58	93
			Hunter	447	Well	-	0.011	25
			Kindred	600	Wells	-	.030	50
			Mapleton	170	Well	0.060	.012	71
			~~[illegible]~~ **	400	Well	-	.025	62
			S.W. Fargo	3,600	Wells	-	.220	61
			W. Fargo	95	~~[illegible] S.W. Fargo~~ ***	-	.006	63

* 625
** Page
*** Wells

Corrections made by State Health Department.

Exhibit No. 2 (Continued)

Municipal Water Supply

Red River of the North Basin Study

Subarea	State	County	Municipality	1963 Population Served	Source of Supply	Rated Plant Capacity MGD	Average Output MGD	GPCD
VI	North Dakota	Barnes	Kathryn	145	Springs	–	0.010	69
			Litchville	375	Wells	–	.015	40
			Tower City	350	Well	–	.012	34
			Valley City	8,000	Wells	3.000	.686	86
			Wimbledon	375	Well	–	.025	67
		Griggs	Cooperstown	1,430	Wells	–	.090	63
			Hannaford	250	Wells	–	.013	60
		Eddy	Sheyenne	400	Well	–	.025	62
		Wells	Harvey	2,700	Wells	–	.25	93
		Ransom	Enderlin	1,600	Well	0.265	.095	59
			Elliott	50	Well	.015	.004	80
			Lisbon	2,087	Well	.860	.150	72
			Sheldon	220	Well	–	–	–
		Sargent	Cogswell	170	Wells	–	–	–
			Forman	550	Wells	–	–	–
			Gwinner	2[illegible]	Wells	–	.010	40
			Rutland	310	Well	.160	.015	48
VII	Minnesota	Becker	Detroit Lakes	6,000	Wells	1.500	.918	153
			Callaway	220	Wells	0.200	.020	91
			Lake Park	700	Wells	.460	.080	114
			Frazee	1,000	Wells	.430	.200	200
		Otter Tail	Fergus Falls	14,000	Otter Tail River	5.000	1.809	129
			New York Mills	780	Wells	–	0.060	77
			Pelicans Rapids	1,600	Wells	0.600	.200	125
			Perham	1,950	Wells	1.010	.135	69
			Battle Lake	650	Wells	0.400	.060	92
		Wilkin	Breckenridge	4,500	Otter Tail River	1.44	.436	97
			Cambell	350	Wells	0.200	.015	43
			Kent	120	Wells	.030	.004	33
			Nashua	100	Well	.020	.005	50
			Rothsay	425	Wells	.230	.065	153
			Wolverton	190	Wells	.042	.015	79
		Grant	Elbow Lake	1,480	Wells	.860	.080	54
			Herman	750	Wells	.110	.030	40
			Norcross	140	Well	.010	.020	143
			Wendell	210	Well	.080	.020	95
		Traverse	Dumont	200	Well	.090	.004	20
			Wheaton	2,000	Wells	.420	.120	60
	North Dakota	Richland	Abercrombie	240	Well	–	.015	62
			Fairmount	610	Wells	–	.036	59
			Hankinson	1,100	Wells	–	.100	91
			Lindgerwood	1,080	Wells	–	–	–
			~~[illegible]~~ ****	160	Wells	–	.008	50
			Wahpeton	6,000	Otter Tail River & Wells	2.1	.400	67
VIII	North Dakota	Towner	Cando	1,580	Well	0.290	.100	63
		Rolette	Rolla	1,400	Wells	–	.120	86
		Pierce	Rugby	2,800	Wells	.300	.160	57
		Benson	Leeds	725	Wells	–	.080	110
			Fort Totten	100	Wells	–	–	–
			Maddock	910	Wells	.300	.085	93
			Minnewaukan	420	Well	–	.025	60
		Ramsey	Devils Lake	6,300	Wells	–	–	–
			Edmore	400	Well	–	.020	50
		Nelson	Lakota	950	Wells	–	.060	63
			McVille	650	Wells	–	.035	53
			Tolna	300	Wells	–	.012	40

Source: Public Health Service 14,15,16,18/ and Minnesota State Department of Health 17/

**** Mcoreton

Correction made by State Health Department.

Exhibit No. 3

Municipal Waste Treatment Facilities

Red River of the North Basin Study

Subbasin Municipality	1960 Population	Estimated Population Sewered	Discharged to	Type of Treatment	P. E. (BOD) Raw	P. E. (BOD) Discharged
Pembina River Basin, N.D.						
Cavalier	1,423	1,330	Land	Lagoon	1,430	0
Langdon	2,151	1,760	intermittent Creek	Lagoon	1,800	0
Neche	565	550	Pembina River	Lagoon	700	0
Pembina	635	485	Pembina River	Lagoon	515	0
Walhalla	1,432	1,000	Pembina River	Lagoon	1,100	0
Park River Basin, N.D.						
Adams	360	330	South Branch Park River	Lagoon	330	0
Crystal	372	360	Cart Creek	Lagoon	360	0
Edinburg	330	310	Middle Branch Park River	Lagoon	340	0
Grafton	5,885	5,640	Park River	Lagoon	85,000 e	-
Hoople	336	300	North Branch Park River	Lagoon	350	0
Milton	284	264	---	Lagoon	264 e	0 e
Osnabrock	289	250	Land	Lagoon	250	0
Park River	1,813	1,540	Land	Lagoon	2,000 e	0
St. Thomas	660	575	Land	Lagoon	575	0
Forest River Basin, N.D.						
Fairdale	126	110	Land	Lagoon	110	0
Fordville	367	310	Land	Lagoon	310	0
Minto	642	550	Land	Lagoon	500	0
Turtle River Basin, N.D.						
Emerado	328	328	---	Lagoon	328 e	0
Grand Forks Air Base	3,000 e	12,000	---	Lagoon	12,000 e	0
Larimore	1,714	1,540	Land	Lagoon	3,320	0
Michigan City	451	400	Land	Lagoon	820	0
Petersburg	272	250	Land	Lagoon	250	0
Goose River Basin, N.D.						
Finley	808	770	South Branch Goose River	Lagoon	940	0
Hatton	856	600	Land	Primary	900	600 e
Hillsboro	1,278	1,300	Goose River	Lagoon	2,640	0
Hope	390	350	Land	Lagoon	475	0
Mayville	2,168	1,820	Goose River	Primary	2,000	1,700
Northwood	1,195	1,000	Land	Lagoon	1,110	0
Portland	606	400	Land	Lagoon	500 e	0
Sharon	251	251	Land	Lagoon	251 e	0
Sheyenne River Basin, N.D.						
Amenia	117	100	Rush River	Primary	100	80
Anamoose	503	480	Land	Lagoon	880	0
Aneta	451	470	intermittent creek	Lagoon	1,000	150
Arthur	325	325	---	Lagoon	325 e	0 e
Balta	165	165	---	Lagoon	165 e	0 e
Binford	261	258	Land	Lagoon	300 e	0
Casselton	1,394	1,000	Swan Creek	Lagoon	1,800	0
Cooperstown	1,424	1,000	Sheyenne	Lagoon	1,060	0
Devils Lake	6,299	5,000	Devils Lake	Lagoon	11,650	0
Enderlin	1,596	1,480	Maple River	Lagoon	1,400	0
Esmond	420	380	Land	Lagoon	450	0
Goodrich	392	350	Sheyenne River	Lagoon	350	0
Hannaford	277	250	Baldhill Creek	Lagoon	250	0
Harvey	2,365	2,000	Sheyenne River	Lagoon	2,500	0
Hunter	446	400	Land	Lagoon	660	0
Kathryn	142	142	Land	Lagoon	142	0
Kindred	580	570	Sheyenne River	Secondary	700	400
Lakota	1,060	1,100	Land	Lagoon	1,660	0
Leeds	797	1,000	intermittent creek	Lagoon	1,000	0
Lisbon	2,093	1,500	Sheyenne River	Secondary	1,680	800
Litchville	365	310	Land	Lagoon	310	0
Maddock	740	700	Land	Lagoon	1,750	0
McClusky	751	600	Land	Lagoon	600	0
McVille	551	500	Land	Primary	800	0
Minnewaukan	620	350	Land	Lagoon	350	0
Page	432	432	Land	Lagoon	432	0
Pekin	180	176	Land	Lagoon	176	0
Rolla	1,398	1,310	Land	Lagoon	1,100	0
Sanborn	263	261	Sanborn Lake	Lagoon	261	0
Sheyenne	423	361	Sheyenne River	Lagoon	360	0
South West Fargo	3,328	3,500	Sheyenne River	Lagoon	11,600	0
Tolna	291	250	Land	Lagoon	250	0
Tower City	300	250	Maple River	Lagoon	250	0
Valley City	7,809	7,030	Sheyenne River	Lagoon	8,570	0
West Fargo	93	139	Sheyenne River	Secondary	159	24
Wimbledon	402	350	Baldhill Creek	Primary	600	300
Wild Rice, Marsh, and Sand Hill River Basins, Minn.						
Ada	2,064	1,860	Marsh River	Secondary	2,200 e	530 e
Climax	310	280	Sand Hill River	None	280 e	280 e
Fertile	968	870	Sand Hill River	None	900 e	900 e
Mahnomen	1,462	1,320	Wild Rice River	Lagoon	1,700 e	0
Shelly	310	280	Marsh River	Lagoon	400 e	0 e
Twin Valley	861	760	Wild Rice River	Lagoon	820 e	0
Ulen	481	430	South Branch Wild Rice River	Secondary	800 e	200 e

Exhibit No. 1
(continued)

Municipal Waste Treatment Facilities

Red River of the North Basin Study

Subbasin Municipality	1960 Population	Estimated Population Sewered	Discharged to	Type of Treatment	P. E. (BOD) Raw	P. E. (BOD) Discharged
Red Lake River Basin, Minn.						
Bagley	1,385	1,250	Clearwater River	Secondary	1,600 e	360 e
Blackduck	765	690	Blackduck Lake	Secondary	1,000 e	730 e
Clearbrook	650	590	Clearwater River	Secondary	650 e	180 e
Crookston	8,546	7,690	Red Lake River	Lagoon	18,800 e	
Fosston	1,706	1,530	Poplar River	Secondary	3,070 e	770 e
Kelliher	297	270	South Branch Battle River	Primary	270 e	190 e
McIntosh	785	710	Poplar River	Secondary	850 e	310 e
Northome	291	260	South Branch Battle River	Primary	260 e	180 e
Plummer	283	250	Clearwater River	Lagoon	[illegible]	0 e
Red Lake Falls	1,520	1,380	Red Lake River	Secondary	[illegible]	[illegible]
Thief River Falls	7,151	6,440	Red Lake River	Secondary	8,600 e	[illegible]
Snake and Tamarac Rivers Basins, Minn.						
Argyle	789	710	Middle River	None	750 e	750
Stephen	858	770	Tamarac River	Primary	770 e	770
Warren	2,007	1,810	Land	Lagoon	1,800 e	0
Two Rivers Basin, Minn.						
Hallock	1,527	1,370	Middle Fork Two Rivers	Secondary	[illegible]	[illegible]
Lancaster	465	400	North Fork Two Rivers	Primary	[illegible]	[illegible]
Roseau River Basin, Minn.						
Roseau	2,146	1,930	Roseau River	Secondary	3,000 e	1,100 e
Wild Rice River Basin, N.D.						
Forman	530	480	Wild Rice River	Primary	600	180
Gwinner	262	200	Land	Lagoon	200	0
Hankinson	1,285	1,160	Wild Rice River	Lagoon	1,000	0 e
Lindgerwood	1,081	1,100	Wild Rice River	Lagoon	1,100	0
Milnor	658	700	Dry Run Ditch	Primary	700	560
Mooreton	186	150	Antelope Creek	Lagoon	150	0
Rutland	300	...	Wild Rice River	Lagoon	300 e	0 e
Wyndmere	644	...	...	Lagoon	610 e	0 e
Bois de Sioux and Mustinka Rivers Basin, Minn.						
Fairmount, N.D.	503	630	Bois de Sioux River	None	1,000	1,000
Donnelly	358	320	Twelve Mile Creek	None	320 e	320 e
Elbow Lake	1,521	1,370	Worm Lake	Secondary	1,400 e	300 e
Graceville	823	740	West Branch Mustinka River	Primary	750 e	600 e
Herman	784	690	Pullman Lake	None	690 e	690 e
Wheaton	2,102	1,890	Mustinka River	Secondary	5,000	1,300 e
Otter Tail River Basin, Minn.						
Battle Lake	733	660	Slough	Secondary	900 e	230 e
Detroit Lakes	5,633	5,070	Pelican River	Secondary	11,200 e	2,800 e
Fergus Falls	13,733	12,360	Otter Tail River	Secondary	16,800 e	4,000 e
Frazee	1,083	970	Otter Tail River	Lagoon	1,300 e	0
New York Mills	828	750	Willow Creek	Secondary	900 e	230 e
Pelican Rapids	1,693	1,520	Pelican River	Secondary	7,100 e	1,800 e
Perham	2,019	1,820	Otter Tail River	Secondary	3,800 e	900 e
Buffalo River Basin, Minn.						
Barnesville	1,632	1,470	Willow Creek	Secondary	15,300 e	3,100 e
Callaway	235	210	Buffalo River	Primary	210 e	140 e
Glyndon	689	660	Buffalo River	Lagoon	660 e	0 e
Hawley	1,270	1,160	Buffalo River	Lagoon	1,300 e	0 e
Lake Park	730	680	Creek to Buffalo River	Secondary	730 e	180 e
Sabin	251	230	...	Secondary	230 e	35 e
Rothsay	457	410	Deerhorn Creek to South Branch Buffalo River	Secondary	410 e	90 e
Main Stem - Red River of the North						
Breckenridge, Minn.	4,335	3,900	Red River of the North	Lagoon	4,160 e	0 e
East Grand Forks, Minn.	6,998	6,100	Red River of the North	Lagoon	18,000 e	-
Halstad, Minn.	639	580	Red River of the North	None	660 e	660 e
Kennedy, Minn.	438	410	Creek to Red River of the North	None	400 e	400 e
Moorhead, Minn.	22,934	20,660	Red River of the North	Secondary	21,200 e	4,200 e
Wolverton, Minn.	206	180	Red River of the North	Primary	200 e	150 e
Abercrombie, N.D.	266	200	Red River of the North	Primary	440	370
Drayton, N.D.	960	910	Red River of the North	Lagoon	930	0
Fargo, N.D.	46,662	47,000	Red River of the North	Secondary	48,700	3,000
Grand Forks, N.D.	34,451	30,000	Red River of the North	Lagoon	38,850	-
Wahpeton, N.D.	5,876	4,700	Red River of the North	Lagoon	4,340	0

Source: Public Health Service 16, 18, 19/ and Minnesota Department of Health 20/

KANSAS CITY 65 09975

Exhibit No. 5

Agricultural Trends*

Red River of the North Basin Study

			Value of Products Sold (Million Dollars)		
Subarea	Number of Farms	Cropland Harvested	Crops Sold	Livestock & Livestock Prod. Sold	All Farm Products Sold
			1959		
I	9,572	2,352,434	70.3	16.8	87.1
II	8,579	1,641,709	48.7	24.3	73.0
III	1,990	670,513	17.6	5.3	22.9
IV	2,185	431,170	9.7	7.0	16.7
V	3,853	1,207,647	31.6	15.4	47.0
VI	6,026	1,972,391	26.1	22.7	48.8
VII	12,666	2,292,213	33.6	53.7	87.3
VIII	5,640	2,154,220	37.4	13.2	50.6
1959 TOTALS	50,511	12,722,297	275.0	158.4	433.4
			1954		
I	11,201	2,695,358	58.6	13.5	72.1
II	10,530	1,871,066	39.6	18.5	58.1
III	2,188	699,369	15.1	3.8	18.9
IV	2,561	460,412	7.4	5.7	13.1
V	4,312	1,282,143	30.5	10.5	41.0
VI	7,003	2,259,771	23.0	15.3	38.3
VII	14,313	2,390,361	31.2	40.9	72.1
VIII	6,546	2,246,270	19.0	9.6	28.6
1954 TOTALS	58,654	13,904,750	224.4	117.8	342.2
			1949		
I	11,799	2,569,200	59.9	13.8	73.7
II	11,436	1,771,824	33.8	20.8	54.6
III	2,314	673,183	14.6	4.4	19.0
IV	2,745	446,235	6.6	6.8	13.4
V	4,497	1,252,716	28.6	12.3	40.9
VI	7,145	2,155,872	21.5	17.4	38.9
VII	15,380	2,422,258	31.0	48.3	79.3
VIII	7,041	2,351,149	29.3	12.5	41.8
1949 TOTALS	62,357	13,642,437	225.3	136.3	361.6

*Adjusted to the 1959 value of the dollar.

Source [32]/

Exhibit No. 6

Value of Mineral Production

Red River of the North Basin Study

(1956 - 1961)
(Million Dollars)*

Subareas	1956	1957	1958	1959	1960	1961
I	.35	.16	.39	.25	.38	.35
II	.67	.63	.77	.73	1.28	1.50
III	.04	.10	.13	.14	.09	.26
IV	-	-	-	-	-	-
V	.77	.72	.58	1.16	1.73	1.26
VI	.16	.20	.24	.53	.44	.50
VII	.30	.12	.13	.28	.26	.40
VIII	.19	.15	.45	.20	.15	.27
TOTALS	2.48	2.08	2.69	3.29	4.33	4.54

*Adjusted to the 1959 value of the dollar.

Source [39]

Exhibit No. 7

Manufacturing Trends*

Red River of the North Basin Study

	1958		1954		1947	
	Number of Establishments	Value Added By Manufacturers (Millions $)	Number of Establishments	Value Added By Manufacturers (Millions $)	Number of Establishments	Value Added By Manufacturers (Millions $)
Subarea I	58	3.0	51	1.6	48	1.1
Subarea II	159	18.2	158	13.3	145	20.2
Subarea III	10	.3	7	.3	9	.3
Subarea IV	13	4.1	13	2.5	13	.3
Subarea V	28	5.0	27	5.9	17	1.0
Subarea VI	30	3.6	25	2.6	24	2.4
Subarea VII	121	10.6	102	7.1	103	5.1
Subarea VIII	11	.6	11	.9	9	.7
TOTALS	430	45.4	394	34.2	368	31.1

* Adjusted to the 1959 value of the dollar.

Source 41/

Exhibit No. 8

Population Trend and Projections

Red River of the North Basin Study

	1910	1920	1930	1940	1950	1960	1980	2015
Subarea I	87,244	93,196	88,670	94,525	84,966	75,766	70,000	65,000
Urban	-	2,512	3,136	4,070	4,901	5,887	12,000	25,000
Rural	87,244	90,684	85,534	90,455	80,065	69,879	58,000	40,000
Subarea II	106,036	120,887	115,602	129,838	130,280	135,446	155,000	210,000
Urban	31,383	35,096	37,825	46,346	56,164	67,104	95,000	180,000
Rural	74,653	85,791	77,777	83,492	74,116	68,342	60,000	30,000
Subarea III	20,161	19,611	19,572	18,493	16,504	15,302	17,000	24,000
Urban	-	-	-	-	-	-	6,000	14,000
Rural	20,161	19,611	19,572	18,493	16,504	15,302	11,000	10,000
Subarea IV	16,695	21,077	20,214	22,800	19,968	17,594	15,000	14,000
Urban	-	-	-	-	-	-	4,000	5,000
Rural	16,695	21,077	20,214	22,800	19,968	17,594	11,000	9,000
Subarea V	53,575	63,257	71,855	78,186	92,240	106,027	138,000	220,000
Urban	19,171	27,681	36,270	42,071	53,126	72,924	138,000	220,000
Rural	34,404	35,576	35,585	36,115	39,114	33,103	-	-
Subarea VI	60,501	66,803	65,605	59,325	54,625	50,849	56,000	58,000
Urban	4,606	4,686	5,268	5,917	6,851	7,809	14,000	20,000
Rural	55,895	62,117	60,337	53,408	47,774	43,040	42,000	38,000
Subarea VII	110,761	122,474	121,804	128,859	124.183	118,766	115,000	109,000
Urban	9,694	14,076	16,240	22,355	27,452	29,577	35,000	62,000
Rural	101,067	108,398	105,564	105,504	96,731	89,189	80,000	47,000
Subarea VIII	66,281	66,555	68,009	66,375	58,926	53,571	54,000	60,000
Urban	5,071	5,004	5,451	6,204	9,334	9,271	13,000	24,000
Rural	61,210	61,551	62,558	60,171	49,592	44,300	41,000	36,000
TOTAL STUDY AREA	521,254	573,860	571,331	598,401	581,692	573,321	620,000	760,000
Urban	69,925	89,055	104,190	126,963	157,828	192,572	317,000	550,000
Rural	451,329	484,805	467,141	471,438	423,864	380,749	303,000	210,000

Source 42,43,44,45,46,48,49,50,58,62/

Exhibit No. 9

Information Pertinent to Water Storage Needs

Red River of the North Basin Study

Water Requirements Per Capita

Water requirements per capita are given in gallons per capita per day, gpcd. Exhibit No. 2, Municipal Water Supply, presents the developed gpcd data in the Red River of the North Basin. These gpcd figures were developed from four sources of information. Data on 21 municipalities in the North Dakota portion of the basin were obtained from a 1963 survey made by the North Dakota State Department of Health. 18/ The Minnesota State Department of Health provided water-use data for 12 continous months during 1963-64 for ten major communities in the basin. 17/ Detailed municipal and industrial water-use data were obtained from three cities during field investigations. 18/ The remaining data were taken from the Municipal Water Facilities Inventory as of January 1, 1963. 15/ Per capita water uses are given for 122 municipalities in Exhibit No. 2.

Because the per capita water-use data have such a wide range, 20 to 200 gpcd, throughout the basin, attempts were made to divide the basin into regions for which more representative gpcd figures could be developed.

The location of each municipal gpcd figure on a map shows a definite pattern. Moving east to west across the basin the gpcd figures decrease. After several groupings along hydrologic and subarea boundaries were attempted, groupings by two "Net Loss From Ponds and Reservoirs" lines were selected. The "Net Loss From Ponds and Reservoirs" isogram shown in Senate Select Print No. 13, "Estimated Water Requirements for Agricultural Purposes and Their Effects on Water Supplies," has a 10 inch and a 12 inch net loss line passing through the basin in a north-south direction. The 10 inch net loss line roughly parallels the Red River, 10-20 miles east of the river, from the international boundary to just east of Ada, Minnesota, and then goes southeast crossing the basin boundary near Otter Tail Lake. The 12 inch net loss line in the basin parallels the Red River, 10-20 miles west of the river. From 10 miles west of Wapheton, North Dakota, the 12 inch net loss line angles southeast toward the Bois de Sioux, crossing it at Mud Lake. These two net loss lines closely correspond to divisions in the gpcd pattern.

To determine whether the per capita water use was different in the larger cities in the basin, the gpcd data in Exhibit No. 2 for selected major cities and for all the municipalities were grouped by the net loss lines. The means of the two sets of data have an eight percent difference. This difference was considered insignificant.

Using all the data, the mean gpcd and the number of municipalities grouped in the region are as follows:

Region	Number of Municipalities	Mean (gpcd)
East of 10 inch net loss line	26	91
Between 10 & 12 inch net loss line	50	85
West of 12 inch net loss line	46	69

Expectations are that the per capita water requirements will increase in the future due to the production of more goods and services to satisfy increased consumer demands resulting from a rise in real income. To meet these expectations per capita water requirements were projected to increase 25 gpcd throughout the basin during the study period, resulting in 95, 110, and 115 gpcd (rounded figures) by the year 2015. These projected figures are in close agreement with the Senate Select Committee's 64/ per capita water use from municipal systems of a 111 and 113 gpcd in Minnesota and 98 and 100 gpcd in North Dakota in the years 1980 and 2000, respectively.

Climatic Information Pertinent to Water Quality Control Storage

For planning purposes the minimum streamflow requirements for quality control are determined by seasons - spring, summer, fall and winter. Considering water temperature, streamflow and assimilative capacity, the seasons are defined as follows: The summer season is from June through September with an average water temperature of 21°C; the spring season is April and May with a water temperature of 10°C; the fall season is October and November with a temperature of 5°C; and the winter season is December through March with a water temperature of 0°C.

The discharges to the stream from stabilization pond waste treatment process are dependent upon precipitation and evaporation. Monthly precipitation in the Sheyenne River Basin, North Dakota, and in the Red Lake River Basin, Minnesota, were used to determine a basinwide pattern. Monthly evaporation data at Devils Lake, Edgelley, and Fargo were studied. The monthly variation in evaporation at Fargo was applied to the annual basinwide evaporation of 31.2 inches. The net difference between precipitation and evaporation on the stabilization ponds is an increase of 0.21 feet of water in the winter and a decrease of 0.12 feet, 0.99 feet, and 0.17 feet of water in the spring, summer and fall, respectively.

Water and Wastes Water Flow Distribution

The variation in monthly municipal water use and seasonal return flows is used in planning water storage needs. The water plant pumpage records for 12 consecutive months in 10 major municipalities and for 36 consecutive months in Fargo and Grand Forks were studied. The variations in monthly municipal water use of five of the municipalities, in which the pumpage to the heavy water-using industries are known and can be excluded, show close agreement and were used to develop a basinwide distribution of monthly municipal water-use.

Grouping of the monthly municipal water-use distribution by seasons gave the summer season as 120 percent, the fall season as 94 percent, the winter season as 85 percent and the spring season as 97 percent of the average annual municipal water use. The assumption is made that the percent of the municipal water requirements returned to the waste treatment facilities will be 80 percent in the summer, 85 percent in the spring and fall, and 90 percent in the winter. The industial waste-water return is assumed to be 90 percent of the industrial water requirements.

Adequate Treatment

Public Law 660 provides ".... storage and water releases shall not be provided as a substitute for adequate treatment or other methods of controlling wastes at the source." Quantities of water required for water quality control are computed on the premise that adequate treatment will be provided. Adequate treatment is defined as 90 percent reduction in BOD with sufficient capacity to provide storage for winter sewage flows. This criteria is based on the following:

(1) The climate and other factors in the basin so influence the economics of waste treatment design that the stabilization pond is almost exclusively used in new plant construction. At present, about two-thirds of all the treatment plants in the basin are stabilization ponds. See Exhibit No. 3.

(2) Minnesota State Department of Health Design Standards require that loading during the month of maximum industrial waste discharge shall not exceed an average of 20 pounds of 5-day BOD per acre, (special consideration is given to seasonal industrial waste discharges) and that storage capacity (above the one foot level in a primary pond) shall be sufficient to provide six months theoretical storage time for design winter sewage flows.

(3) The North Dakota State Department of Health stabilization pond design features call for 120 days of winter detention with BOD loadings of 20 pounds per acre per day.

(4) The experiences of both health departments show that the reduction in the BOD should always be greater than 90 percent with an average reduction in BOD of 95 percent in the properly designed, operated and maintained stabilization pond.

(5) The total waste load of an area seldom passes through the waste treatment plant. Considering storm water overflow, surface runoff, and agricultural return flows, less than 95 percent BOD reduction is assumed to provide protection to the stream against these unmeasured waste loads.

Plant Operation and Release Schedule

The required storage capacity for winter sewage permits control of necessary releases. The North Dakota State Department of Health recommends that discharges be made during the spring runoff and in the fall before freeze-up occurs.

Because of the evaporation and seepage, waste discharges to the stream are not required from some stabilization ponds especially in the western portion of the basin. Evaporation and precipitation are accounted for in calculating the amount of discharge to the stream. There is little information on seepage from ponds. The amount of seepage is considered highly variable and dependent upon local soil condition and construction practices. In the discharge calculations seepage is considered insignificant. Controlled construction practices, selective materials and the clogging of the soil pores with sewage solids are expected to minimize seepage in the future.

The operating procedure use in these calculations is: Spring releases are controlled to maintain a water level at not less than 2.5 feet. Releases are made in June if the summer inflow will raise the water level above 5-feet before the fall drawdown. In the fall the water level will be drawn down to provide storage for the winter sewage flows.

The amount of discharge necessary each season was calculated on two operating schedules. (1) Ponds were designed on the limitation of 20 pounds of 5-day BOD per acre and sufficient storage between the 1 and 5-foot levels for winter sewage flows. In this design, the discharges were calculated on the basis of operating the pond as a single cell, and water levels were not drawn down below the 2.5 and 1.0 foot levels in the spring and fall, respectively. This design and operating procedure was considered impractical at trading centers with large, concentrated, industrial waste. (2) Multi-cell ponds were designed with sufficient storage for winter sewage flows. Spring discharges were calculated on the winter and spring inflow. Fall discharges were calculated on the summer and fall inflow. Discharge calculations were based on emptying most of the cells. Many operating procedures would be possible. The two used are considered most probable.

Oxygen Sag Factors

In the use of the oxygen sag formula, several factors must be determined in calculating minimum streamflow requirements to meet DO quality objectives. These factors are dependent upon the turbulence of streamflow, time of travel between waste discharges, the type of waste discharged, stream conditions above and below the point of waste discharge, etc. The factors used in the calculations are based on the study of these variable conditions. The range of factors used by seasons in this study is as follows:

Item	Spring	Summer	Fall
Steam "Self Purification," f	1.8 - 4.0	1.5 - 2.9	2.0 - 4.7
Upstream DO Saturation (%)	80 - 95	80 - 95	80 - 95
Upstream BOD (mg/1)	2 - 10	3 - 8	2 - 12
Waste Effluent DO (mg/1)	2 - 4	2 - 3	3 - 4
Average Temperature (^{o}C)	10	20	5

Exhibit No. 10

Garrison Diversion Unit

Red River of the North Basin Study

The Missouri-Souris Unit, a plan for irrigating lands in North and South Dakota, was authorized by Congress as described in Senate Document 191, 78th Congress. The Garrison Diversion Unit is a modification of that plan submitted to Congress for authorization. In the transmittal to the President of the Garrison Diversion Unit report, the Secretary of the Interior recommended construction of the necessary works to irrigate an area of 250,000 acres. [80]

The report on the Garrison Diversion Unit [80] presents a plan for diversion of water from Garrison Reservoir on the Missouri River for irrigation of 1,007,000 acres, municipal and industrial use in 41 cities, fish and wildlife uses and recreation purposes in Devils Lake and other impoundments. Construction of the proposed project in stages is recommended.

With the development of the Garrison Unit to its ultimate size of 1,007,000 acres, return flows occurring annually to the Sheyenne River are estimated at 260,000 acre-feet. [83] These flows, together with anticipated diversion of return flow from the East Souris Canal, are estimated to average 563,000 acre-feet. [61] Average monthly return flows could be expected to range from 120 cfs in winter months to 1,400 cfs in summer, with extremes from 100 to 1,700 cfs. In addition, 36,520 acre-feet per year of return flow could be expected through the Wild Rice River. [83]

In May of 1963, a Supplemental Report on the Garrison Diversion Unit (initial stage - 250,000 acres) [45] stated: "The plan for the initial stage is multi-purpose. It is based on the studies made for the million-acre Unit, and on detailed investigation of some of those portions included in the initial stage... The proposals made for the initial stage take into account their inclusion in an ultimate development of about one million acres.

"The initial stage provides for irrigation of 250,000 acres, a municipal and industrial water supply for 14 cities, fish and wildlife development at 36 major areas and a number of smaller areas and recreation development at 9 major water impoundments. Flood control and incidental drainage of nonirrigable lands are other benefits. It includes Jamestown Dam and Reservoir (already constructed) and the restoration of Devils and Stump Lakes for recreation, fish and wildlife conservation, and industrial water supply."

Among the acres to be irrigated are the Oakes area of 45,980 acres, the Warwick-McVille area of 47,220 acres, and New Rockford area of 20,935 acres. [45] The return irrigation flows from a portion of the Warwick-McVille and the New Rockford areas will drain to the Sheyenne River. The return irrigation flows from a portion of the Oakes area will drain to the Wild Rice River.

The peak irrigation return flows are estimated to usually result in August with the minimum return flows occurring in the late winter months. Estimated return flows, with full development of initial stage lands and without regulation in Baldhill Reservoir, will result in the following variations in accruals and capacities to the Red River: [82]

	Maximum	Average	Minimum
Annual Return Flows (Acre-feet)	79,000	66,000	55,000
Capacities (Cubic feet per second)	313	92	6

It is estimated that average annual return flows in the Red River Basin from the 250,000 acre project will occur as follows: [61]

Sheyenne River	45,000 acre-feet
Wild Rice River	21,000 acre-feet
Devils Lake	7,000 Acre-feet

Most of the return flow will have been used once for irrigation and would have increased in total dissolved solids. It is estimated that undiluted return flows will contain an average concentration of about 1,350 mg/l TDS. [82] This is exclusive of what effect flushing of Devils Lake may have on quality of flows in the Sheyenne River.

The proposed restoration of Devils and Stump Lakes by flushing would result in outflow draining into the Sheyenne River. The outlet capacity from Stump Lake to the Sheyenne River has been set at 200 cfs which would be the maximum release.

No definite plan for restoration of Devils and Stump Lakes has been proposed. After initial filling, dilution water will be required during the flushing period to maintain tolerable salt concentrations in the Sheyenne and Red Rivers. [85] The period of time taken for flushing and the extent to which the quality is improved will be the controlling factors.

The final plan for restoration of the lakes and for operating them will be determined by local and fish and wildlife interests. The filling and flushing process will go on in the early stage of initial development when there will be surplus capacity in the Principal Supply Works to blend with the effluent from the lake chain. After the flushing process is complete, an average dilution volume of 15,000 acre-feet annually has been provided in the initial stage diversions, in excess of the evaporation requirements, to aid in the control of water quality. As presently planned, this volume will be released to the Sheyenne River and accrue to Baldhill Reservoir and the Red River.

Thus, the total volume of accruals to the Red River, with Devils and Stump Lakes restoration and irrigation return flows from initial stage development of the Garrison Diversion Unit, will increase by an average of 15,000 acre-feet annually over those given previously for irrigation return flows alone. The average annual volume of return flows and restoration effluent will increase to about 81,000 acre-feet with no change in the maximum and minimum capacities expected from regulation, while the average capacity will increase by about 21 cfs, or from 92 cfs to 113 cfs.

A 1957 Bureau of Reclamation schedule 80/ for the restoration of the Devils and Stump Lakes chain gave a period of eight years to fill Stump Lake, the last lake in the chain. In accordance with the schedule, after inflow starts, 8 and 12 years would be required to lower the dissolved solids in Stump Lake to 3,000 and 1,500 mg/l, respectively.

Dissolved solids in Garrison Reservoir are expected to increase from 420 mg/l under present streamflow conditions, to 500 mg/l under future conditions of upstream use and storage. 80/ This concentration is expected to have increased to 540 mg/l of TDS when delivered for flushing of Devils Lake. A continual discharge of the maximum 200 cfs from Stump Lake would amount to about 145,000 acre-feet per year. With a diversion, plus approximate average natural inflow of 190,000 acre-feet at a concentration of 500 mg/l of dissolved solids the outflow to the Sheyenne would be 139,000 acre-feet per year. 85/ Thus, an inflow of 190,000 acre-feet to the lakes would be close to the maximum with the planned 200 cfs outflow limitation. Overflow to the Sheyenne River would start about six years after beginning a diversion of this magnitude to Devils Lake. 85/ The concentration of dissolved solids when this overflow first begins is likely to be 10,000 to 13,600 mg/l. 85/ Concentration would remain high for several years after overflow started. The concentration of dissolved solids in Stump Lake should approach 1,000 to 1,500 mg/l after about six years of overflow at 139,000 acre-feet per year. 85/